

**NON-TOXIC CORROSION-PROTECTION RINSES AND SEALS
BASED ON RARE EARTH ELEMENTS**

CROSS-REFERENCE TO RELATED APPLICATIONS

5 This application is a continuation-in-part of commonly assigned U.S. Application Serial No. 10/038,150, filed January 4, 2002 and entitled "NON-TOXIC CORROSION-PROTECTION RINSES AND SEALS BASED ON COBALT." This application is also related to U.S. Application Serial No. __/__, __ (Attorney Docket No. UVD 0279 IA), filed ____, 2003 and entitled "NON-TOXIC CORROSION-PROTECTION PIGMENTS BASED ON RARE
10 EARTH ELEMENTS", which is a continuation-in-part of U.S. Application Serial No. 10/037,576, filed January 4, 2002 and entitled "NON-TOXIC CORROSION-PROTECTION PIGMENTS BASED ON COBALT", and U.S. Application Serial No. __/__, __ (Attorney Docket No. UVD 0280 IA), filed ____, 2003 and entitled "NON-TOXIC CORROSION-PROTECTION CONVERSION COATS BASED ON RARE EARTH ELEMENTS", which is a
15 continuation-in-part of U.S. Application Serial No. 10/038,274, filed January 4, 2002 and entitled "NON-TOXIC CORROSION-PROTECTION CONVERSION COATS BASED ON COBALT", the disclosures of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

20 This invention relates generally to compositions and methods for the formation of protective, corrosion-inhibiting rinses and seals for use to impart additional corrosion resistance to structural materials without the use of chromium in the hexavalent oxidation state. More particularly, this invention relates to non-toxic, corrosion-protective rinses and seals for metal phosphating, anodizing, and "black oxidizing" processes based on tetravalent cerium,
25 praseodymium, or terbium and methods of making and using the same.

 Metals like aluminum, zinc, titanium, iron, cadmium, tin, indium, lithium, beryllium, magnesium, niobium, tantalum, zirconium, lead, rare earths, copper, and silver, their alloys, or items plated with these metals, require protection from corrosion due to their low oxidation-reduction (redox) potentials or ease of oxide formation. These metal alloys have many uses that
30 range from architectural adornments, to protective coatings themselves, to automotive, structural aerospace, and electronic components, to name a few. The unalloyed metals typically form an

outer layer of natural oxide: a “passive film” that serves to protect them and reduce their overall rate of corrosion. However, the corrosion protection offered by the naturally formed oxide layer on certain alloys of these metals is not complete and corrosion will eventually occur unless some form of additional corrosion protection is used. Thus, for example, steels are typically

5 “phosphated” to provide an impermeable coating that not only resists corrosive attack, but also provides a paint base. Additionally, architectural and structural aluminum are frequently “anodized” to form an impermeable oxide film for the same reasons.

Inhibiting the initiation, growth, and extent of corrosion is a significant part of component and systems design for the successful long-term use of metal objects. Uniform
10 physical performance and safety margins of a part, a component, or an entire system can be compromised by corrosion.

One method of enhancing the corrosion resistance of these alloys includes the use of a chemically- or electrolytically-generated coating such as an anodized coating (typically on aluminum), a phosphate coating (typically on electrogalvanized or bare steel), or a black oxide
15 coating (for high strength bearing and tool steels). The metal is exposed to a compound that chemically alters the surface (in phosphating and black oxidizing) or an electric current (in anodizing) and forms a coating that provides some corrosion resistance by forming a barrier film. The morphology and possibly the chemistry of the anodic coating or phosphate coating can allow for the formation of a strong bond with subsequently-applied paint systems. An anodic coating
20 is usually applied via immersion in an electrolytic cell. A phosphating or black oxide solution may be applied by immersion, by spray, or by manual means.

These coatings frequently exhibit “flaws” such as pores, pinholes, or thin portions in the coating after formation and do not contain any inherent means to “repair” these coating breaches. The application of a second solution is necessary to fill the pores in the coating and deposit
25 compounds that will act as long-term corrosion protective species. These “second solutions” are termed “rinses” or “seals” in the corrosion literature. The term “rinse” is typically used for the second solution applied to phosphating and black oxide coatings, whereas the term “seal” usually refers to the second solution applied to anodic coatings. These rinses and seals are typically applied via spray techniques, but immersion, fogging, and wiping are also accepted practices.

30 Hexavalent chromium has traditionally been the active corrosion-inhibiting agent used in rinses and seals for the formation of protective coatings for iron, electrogalvanized iron,

aluminum, zinc, magnesium, titanium, cadmium, tin, indium, lithium, and their alloys. Niobium, tantalum, zirconium, beryllium, lead, rare earths, copper, and silver may also be treated with hexavalent chromium rinses and seals for special applications. The three main coating processes that use these rinses and seals are 1) the phosphating process for steel and galvanized steel products, 2) the anodization process for a host of structural metals, and 3) the black oxide process for high-strength steel and iron used for bearing materials. Table 1 illustrates the processes that typically utilize a final chrome “rinse” or “seal” to impart additional corrosion protection to a given substrate material.

10 **Table 1 – Current Rinse and Seal Processes Using Hexavalent Chromium**

Process	Comments/ Examples	Substrate Metals	Government/ ASTM/Mil Specs
Rinses for zinc phosphating on steel, steel products, and nonferrous alloys	Used as a paint base on all automotive bodies, also for some coil and sheet stock. Used as a lubricating layer on tooling dies.	Zinc-coated steel, zinc, or bare steel are usual substrates. Also for aluminum, magnesium, copper, titanium, cadmium, and silver in less common applications.	MIL-P-50002 DoD-P-16232 MIL-HDBK-205 SAE-AMS2481 QQ-P-416
Seals for anodized aluminum including sulfuric, chromic, oxalic, boric, sulfonated organic acids, citric, and phosphoric acid anodizing	Used extensively for architectural and decorative applications, adhesive bonding, siding, etc. Also used as a paint base.	Aluminum and aluminum alloys	MIL-A-8625 SAE-AMS2470 ASTM B580 ASTM D1730 AA46-78
Rinses for iron phosphating on bare steels	Used as a paint base on coil coatings for general appliance and siding applications. Different from Zn and Mn phosphating.	Steel and iron alloys	TT-C-490 MIL-HDBK-205 SAE-AMS2481 QQ-P-416
Rinses for manganese phosphating on steel and steel alloys, also on nonferrous alloys	Used solely as a solid lubricant, not as a paint base. Used extensively on bearing materials.	Mostly bare steel. Can also be used on high-strength copper alloys.	MIL-P-50002 DoD-P-16232 MIL-HDBK-205 SAE-AMS2481
Rinses for “black oxide” and other	Used solely as a solid lubricant, not as a	Mostly bare steel. Can also be used on	MIL-C-13924 MIL-C-46110

oxide lubricating layers	paint base. Used extensively on bearing materials.	high-strength copper alloys.	SAE-AMS2485
Seals for anodized magnesium including sulfuric, chromic, oxalic, boric, sulfonated organic acids, citric, and phosphoric acid anodizing	Used as a paint and adhesive base.	Magnesium and magnesium alloys	MIL-M-45202 ASTM D1732 SAE-AMS2475 MIL-C-13335
Seals for anodized titanium including sulfuric, chromic, oxalic, boric, citric, hydrofluoric, and phosphoric acid anodizing	Used as a paint and adhesive base.	Titanium and titanium alloys	SAE-AS4194 SAE AMS-2488
Seals for anodized zinc including sulfuric, chromic, oxalic, boric, sulfonated organic acids, citric, and phosphoric acid anodizing	Used as a paint and adhesive base.	Zinc and zinc alloys	MIL-A-81801
Seals for anodized steel including sulfuric, chromic, oxalic, boric, and phosphoric acid anodizing	Used as a paint and adhesive base.	Iron, steel, and steel alloys	QQ-P-35
Seals for anodized copper, cadmium, silver, tantalum, lead, cobalt, niobium, zirconium, tin, indium, and manganese including sulfuric, chromic, oxalic, boric, sulfonated organic acids, citric, and phosphoric acid anodizing	Used for a number of applications, principally as a paint and adhesive base. For example, niobium and tantalum capacitors, cadmium plate, silver solder, and zirconium for nuclear applications.	Copper, cadmium, silver, tantalum, niobium, zirconium, tin, indium, manganese and their alloys	QQ-P-416

As shown in Table 1 above, there are three “generic” phosphating processes for steel and steel alloys – zinc, manganese, and iron phosphating. Differences in the coating solutions result in different chemistries and physical attributes in the formed coatings. For example, zinc phosphating is used primarily on galvanized steel sheet, and results in an ideal surface

5 morphology for paint adhesion if the crystals are small in size, and as a solid lubricant for larger size crystals. Manganese phosphating, however, results in a hard, lubricious coating that has no use as a paint base, but exhibits excellent characteristics as a solid lubricant. Manganese phosphating coatings are rarely subjected to a post-chrome rinse, because the corrosion resistance of these coatings is of lesser concern. Iron phosphating is also used as a paint and
10 adhesive base, and always receives post-treatments for corrosion protection.

Similar differences are also noted in anodizing processes. Anodizing processes involve the application of an electric potential under a variety of acidic conditions to the substrate to be coated. Sulfuric acid is the conventional anodizing acid used to form hard oxide films on aluminum, although other anodization solutions have specialized applications. For example,
15 phosphoric acid may be used for adhesive bonding applications on aluminum. Oxalic acid anodization results in a harder, denser coating with higher corrosion resistance than sulfuric acid anodization and is used more often in Europe. Boric acid anodization is used frequently for electronic capacitors although citric and tartaric acid anodization can be used for the same application. Anodization with sulfonated organic acids (such as sulfosalicylic or sulfophthalic
20 acids) is used to impart color during the anodization process. Chromic acid anodization is used on parts with complex shapes where final sealing or rinsing is not possible. Other acids, including hydrofluoric acid, have been used for special applications or in proprietary formulations. Those skilled in the anodization art know that a wide variety of anodizing processes exist due to the multitude of substrate metals, anodizing acids, applied voltages, and
25 final applications.

Finally, “black oxide” coatings are applied to high strength steels and copper-containing alloys to impart a lubricious coating. The difference between “black oxide” coatings and other lubricious coating processes (such as manganese phosphating) is that “black oxide” coatings are applied under caustic, elevated temperature conditions. For example, a concentrated sodium
30 hydroxide solution is raised to its boiling point and the substrate metal is then immersed in this

solution. This results in the formation of a lubricious coating of magnetite/ferrite on the surface of steel alloys.

Other coating processes that result in coatings with no inherent self-healing characteristics have also been enhanced through the use of hexavalent chromium rinses and seals. Carbonate coatings on metals such as zinc, iron, magnesium, and especially copper have been described in the early literature as providing some degree of corrosion protection. These coatings can be further enhanced through the use of hexavalent chromium rinses to deposit inhibiting compounds to self-heal coating breaches. Other oxide, phosphate, oxalate, silicate, aluminate, borate or polymeric coatings, or combinations thereof, can also be enhanced via hexavalent chromium rinses and seals.

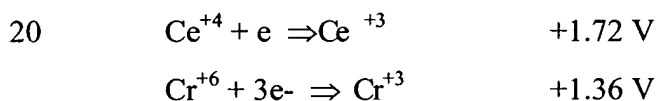
For each of these three generic coating processes (phosphating, anodizing, and black oxidizing), a second, subsequent chemical treatment is often applied. The nature of this second treatment is dependent upon the desired final characteristics of the metal piece. For phosphating and black oxidizing processes, this second treatment is usually a rinse of hexavalent chromium, to impart additional corrosion protection to the coating. For anodizing processes, the second treatment can impart a number of useful attributes to the work piece. This second “sealing” process for anodized coatings can include: 1) pure boiling water (to plug the pores with a hydrated alumina composition); 2) silicates (to plug the pores with a silicate composition); 3) dyes or metal-dye complexes (to impart color to the anodic coating); 4) metal salts followed by cathodic reduction (to color the coating via the formation of metals or metal sulfides in the pores); 5) lubricating additives such as molybdenum disulfide or dispersions of polytetrafluoroethylene (to fill the pores with a lubricious additive); and 6) hexavalent chromium seals to fill the pores with chromate species. It is noteworthy that the only one of these six generic sealing processes that results in a coating with self-healing characteristics is the hexavalent chromium seal. The other sealing processes for anodic coatings may temporarily increase the corrosion resistance of the coating by plugging the pores in the oxide coating (e.g., with hydrated alumina or silicate), but the coating does not retain any corrosion-inhibitive species.

The various coating processes to which the art described in this invention is applicable are shown in Table 1 above. The frequent use of hexavalent chrome to “rinse” or “seal” the coating (phosphate, anodic, or black oxide) formed in the first unit operation of the process to

impart additional corrosion resistance connects them. These solutions are usually simple formulations consisting of nothing more than dissolved chromium trioxide, chromate, or dichromate. These formulations are usually applied by spraying, although immersion, fogging, or even wiping may also be used.

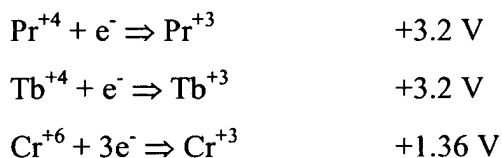
- 5 Sometimes these hexavalent chromium rinse or sealing formulations will contain other constituents. Some formulations include minor concentrations of fluorides. These fluorides act to “etch back” the coating formed in the first unit operation (e.g., phosphate, anodic, or black oxide), thus further facilitating the deposition of corrosion-inhibiting species. Rinsing solutions for phosphate solutions are frequently observed to include phosphoric acid in addition to
 10 hexavalent chromium in order to reduce staining of the phosphate coating by the hexavalent chromium. These hexavalent chromium rinse or sealing solutions can also contain other constituents, such as ferricyanides or molybdates. The presence of these other constituents is significant in light of the chemistry developed and presented herein.

Significant efforts have been made to replace chromium with other metals for corrosion-
 15 inhibiting applications due to toxicity, environmental, and regulatory concerns. Cerium is one non-toxic, non-regulated metal that has been considered as a chromium replacement. Cerium (like chromium) exhibits more than one oxidation state (Ce^{+3} and Ce^{+4}). In addition, the oxidation-reduction potential of the Ce^{+4} - Ce^{+3} couple is comparable to the Cr^{+6} - Cr^{+3} couple. For example, in acid solution:



Praseodymium and terbium also exhibit more than one oxidation state (Pr^{+3} and Pr^{+4} , Tb^{+3} and Tb^{+4}). Tetravalent praseodymium and terbium are even stronger oxidizing agents than cerium (with calculated redox potentials of +3.2 V in acidic solution – Nugent, L.J., et al., *J. Inorg.*

25 *Nucl. Chem.* 33: 2503-30, 1971):



Accordingly, several processes have been reported in the literature, which make use of cerium in
 30 rinsing or sealing bath solutions. However, the coatings formed by these processes provide only limited corrosion protection and do not approach the benefit derived from the use of hexavalent

chromium. None of the prior art recognizes the need to “valence stabilize” tetravalent cerium to ensure its long-term stability, nor the need to form tetravalent cerium compounds of optimum solubility characteristics.

The use of film-forming substances, such as polymers, silicates, sol-gel, etc., which have
5 no inherent oxidizing character in sealing or rinsing coating solutions, has been described in the literature. The film formers may enhance short-term corrosion resistance by functioning as a barrier layer. Barrier layers lacking an active corrosion inhibitor have been demonstrated to be capable of inhibiting corrosion as long as the barrier is not breached, as by a scratch or other flaw. Film formers can actually enhance corrosion on a surface after failure due to the well
10 known effects of crevice corrosion.

1) Rinses for Phosphate Coatings

U.S. Patent No. 2,790,740 to Ayres et al. describes the use of a tetravalent cerium compound (i.e., ceric sulfate) as an accelerator for phosphate coatings on aluminum and zinc.
15 The cerium is added simultaneously with the phosphate treatment. No provisions for post-treatment of the formed phosphate coating through an additional rinse are described. Pores formed during the phosphating step are therefore not sealed. This patent also describes the need to incorporate zinc or manganese compounds with the cerium, as cerium appears to be effective only when used in the presence of substantial proportions of zinc or manganese.

20 U.S. Patent No. 2,698,266 to Thirsk describes the use of hexavalent chromium/tetravalent cerium rinses to seal phosphate and arsenate coatings on aluminum. The use of hexavalent chromium in conjunction with tetravalent cerium represents no appreciable reduction in bath toxicity.

German Patent No. DE 40 41 091 A1 to Metallgesellschaft AG describes the use of
25 trivalent cerium along with tetravalent cerium in a 2:1 to 9:1 ratio for the passivating of phosphated coatings on steel and aluminum. These coating solutions also incorporate fluoride, carboxylate, hydroxycarboxylate, aminocarboxylate, molybdate, and/or tungstate ions in the solution. However, the importance of tetravalent cerium within the formed coating, the “valence stabilization” of this ion, and the solubility ranges for formed tetravalent cerium compounds are
30 not described.

2) Seals for Anodic Coatings

U.S. Patent No. 5,192,374 to Kindler describes the formation of an aluminum oxide (boehmite) coating on structural aluminum, followed by treatment with a soluble cerium salt and a metal nitrate at 70°C to 100°C to form cerium oxides and hydroxides for increased corrosion resistance. The formed oxides and hydroxides are described as filling the pores in the boehmite coating. Also, Stoffer et al. in U.S. Patent No. 5,932,083 describe the use of a solution containing cerium and an oxidizing agent for treatment of aluminum alloys. The aluminum-containing substrate is electrolyzed in this solution, forming a mixed aluminum oxide/cerium oxide (or hydrated cerium oxide) coating on the aluminum as a barrier film. The formation of tetravalent or hydrated tetravalent cerium oxide is described. However, neither Kindler nor Stoffer et al. teach the use of “valence stabilizers”, which are important for use of tetravalent cerium compounds having aqueous solubilities that are sufficiently high to ensure long-term self healing of the coating. The cerium oxides and hydrated oxides described in these patents function merely as pore-filling barrier layers, and not as active self-healing inhibitors within the coating. Further, the use of tetravalent cerium oxides and hydroxides as corrosion inhibitors results in lower corrosion performance, as is described herein, due to the fact the electrostatic double layers around these species are much smaller than those exhibited by tetravalent cerium species containing 50% or less oxide or hydroxide as attached ligands.

U.S. Patent Nos. 5,635,084; 5,582,654; and 5,194,138, all to Mansfield et al., describe methods for treating the surface of an aluminum alloy having a relatively high copper content, so as to make the surface resistant to corrosion. The method comprises: a) removing substantially all of the copper from the surface of the alloy, b) contacting the surface with a first solution containing cerium, c) electrically charging the surface while contacting with an aqueous molybdate solution, and d) contacting the surface with a second solution containing cerium. U.S. Patent No. 5,756,218 to Buchheit et al. describes a process for the corrosion protection of metallic materials that includes sealing a coating with an aqueous solution consisting essentially of at least one soluble metal salt (i.e., Ce). However, the ‘084, ‘654 and ‘218 patents make use of hexavalent chromium in the coating process, and so no advantage in toxicity reduction is achieved. Moreover, electrolysis will only oxidize cerium to the tetravalent state in the outer regions of the already-formed cerium-containing coating. The importance of tetravalent cerium and the functional parameters for tetravalent cerium-containing complexes are not described in

any of these prior art references.

U.S. Patent No. 6,022,425 to Nelson et al. describes the application of a corrosion-resistant coating for aluminum based on cerium, which cerium is oxidized to the tetravalent oxidation state, resulting in the formation of tetravalent or hydrated cerium oxides. However, these references teach tetravalent cerium compounds having aqueous solubilities that are so low they function as barrier films or sealants, rather than active corrosion inhibitors. Moreover, the use of valence stabilizers for forming complexes with tetravalent cerium is not disclosed.

European Application No. EP 0 902 103 A1 by Nippon Steel Corporation describes the application of a trivalent cerium solution with organic oxoacids to aluminum or galvanized steel.

U.S. Patent No. 6,200,672 B1 to Tadokoro et al. describes the use of rare earth and/or Group IVA solutions with selected organic molecules for treatment of metal surfaces. U.S. Patent No. 5,964,928 to Tomlinson describes the use of a Group IVA compound (i.e., zirconium, titanium, or hafnium) in combination with a rare earth element and optionally a fluoride. European Application No. EP 0 839 931 A2 by Nihon et al. describes an aqueous, metallic surface treating solution comprising a metal element including Ce, an oxidizing source, and an oxyacid or oxyacid salt of phosphorus or an anhydride thereof. However, none of these references teach the presence of a valence stabilized, oxidized rare earth element such as cerium, praseodymium, or terbium in the formed seal, whose availability to the corroding system is controlled via the solubility of the oxidized rare earth compounds. In order to function as a true replacement for hexavalent chromium, which is itself a highly oxidized species, the rare earth compound must be oxidized in the formed seal.

U.S. Patent No. 6,206,982 B1 to Hughes et al. describes the use of a four component system to provide corrosion protection of aluminum. One of these components includes a rare earth compound, especially cerium.

The use of colloidal suspensions of tetravalent cerium oxide (CeO_2) in anticorrosive coatings is described in U.S. Patent Nos. 5,922,330 and 5,733,361 to Chane-Ching et al.; PCT International Publication No. WO 96/26255 by Rhone Poulenc Chimie; and PCT International Publication Nos. WO 01/36331 A1 and WO 01/38225 A1 by Rhodia Terres Rares. The CeO_2 exhibits a solubility that is too low for effective release of corrosion-inhibiting tetravalent cerium ions.

An aqueous dispersion of a cerium compound with other rare earths, transition metals, aluminum, gallium, or zirconium is described for anticorrosive agents in PCT International Publication No. WO 01/55029 A1 by Rhodia Terres Rares. Similarly, an aqueous dispersion of cerium oxide in combination with additives such as beta-diketones, alpha-hydroxycarboxylic acids, beta-hydroxycarboxylic acids, or diols is described for anticorrosive agents in U.S. Patent No. 6,033,677 to Cabane et al. Neither of these references define the need for cerium to be in the tetravalent oxidation state to achieve anticorrosive effects.

The following U.S. patents and published applications provide further examples of corrosion-inhibiting seals from metallic surfaces: U.S. Patent No. 6,248,184 B1 to Dull et al.; U.S. Application Publication No. 2002/0003093 A1 by Dull et al.; U.S. Application Publication No. 2003/0019391 A1 by Kendig; U.S. Application Publication No. 2003/0024432 A1 by Chung et al.; U.S. Application Publication No. 2002/0033208 A1 to Krishnaswamy, Jr.; U.S. Patent No. 6,451,443 B1 to Daech; and U.S. Patent No. 6,299,983 B1 to Van Alsten. However, none of these references teach the need for at least one rare earth element to be in the tetravalent oxidation state.

Accordingly, the need remains for improved rinses and seals which have an effectiveness, ease of application, and performance comparable to coatings formed with hexavalent chromium and which do so without the use of toxic or currently regulated materials.

SUMMARY OF THE INVENTION

This need is met by the present invention which represents a significant improvement in the formulation of non-toxic rinses and seals through the use of tetravalent cerium, praseodymium, or terbium. Although the present invention is not limited to specific advantages or functionality, it is noted that the rinses and seals of the present invention inhibit corrosion to a higher degree than any other known cerium-based coating. Moreover, the rinses and seals of the present invention inhibit corrosion to a degree comparable to commercial formulations based on hexavalent chromium. As used herein, the term “sealing bath” includes both sealing baths and rinsing baths and the term “seal” includes both seals and rinses.

The present invention utilizes “valency stabilization” of the tetravalent cerium, praseodymium, or terbium ion in the as-formed coating to achieve corrosion resistance that is comparable to hexavalent chromium. More specifically, in order to achieve a high degree of

corrosion resistance, a rinse or seal can result in a coating that exhibits the following characteristics:

- 1) The coating can contain an oxidizing species. The coatings that are subjected to rinsing and sealing (e.g., phosphate, anodic, or black oxide) do not contain oxidizing species. Therefore, the sealing or rinsing solution must supply these oxidizing species. Oxidizing species serve two important functions within the coating: a) they act to impede the flow of charged species through the coating, therefore helping reduce the transport of corrosion reactants, and b) if a scratch is formed in the coating, these oxidizing species act to “repair” the breach by oxidizing the underlying metal and quickly reforming an oxide barrier. The effectiveness of the oxidizing species is a function of its individual oxidation-reduction potential and the more highly oxidized species exhibit greater corrosion protection. An oxidation-reduction potential of approximately +0.80 V (at a pH of 0) appears to be the dividing line between inhibitors that offer some corrosion protection and those that do not. The tetravalent cerium ion, with an oxidation-reduction potential of +1.72 V (at a pH of 0), is an exceptionally good oxidizing species. Tetravalent praseodymium and terbium are even stronger oxidizing agents, with reported oxidation-reduction potentials of +3.2 V at a pH of 0. The hydroxyl and oxygen liberated from water when tetravalent cerium, praseodymium, or terbium is reduced will oxidize (“passivate”) nearby bare metal.
- 2) A “valence stabilizer” for the tetravalent cerium, praseodymium, or terbium can be employed to ensure that the ion will not be reduced quickly to the trivalent state in solution or in the coating. The importance of stabilizing the cerium, praseodymium, or terbium ion in its tetravalent state in a solid precipitate is important to the composition of rinsing and sealing formulations.
- 3) The tetravalent cerium, praseodymium, or terbium species formed in the coating (e.g., in the pores) must be present as a “sparingly soluble” material. If the formed tetravalent cerium, praseodymium, or terbium species is too soluble, then it will be washed away. If it is too insoluble, then insufficient tetravalent cerium, praseodymium, or terbium is available to inhibit corrosion. A tetravalent cerium, praseodymium, or terbium species that exhibits low solubility

will not only fail to inhibit corrosion, but can also promote localized crevice corrosion and result in enhanced corrosion rates. In order to form an effective rinse or seal, the tetravalent cerium, praseodymium, or terbium compounds formed in the coating pores must be in a “sparingly soluble” form. It is difficult to place specific solubility values to these optimum “sparingly soluble” coating materials because there appear to be several variables associated with what makes an optimum coating material. If the tetravalent cerium, praseodymium, or terbium is incorporated in the coating in the form of a tetravalent cerium, praseodymium, or terbium/valence stabilizer complex which exhibits a solubility in water of between about 5×10^{-5} and about 5×10^{-2} moles per liter of tetravalent cerium, praseodymium, or terbium, then appreciable corrosion inhibition will be observed. Coatings that incorporate stabilized tetravalent cerium, praseodymium, or terbium compounds that fall outside of this particular solubility range may also exhibit some corrosion inhibition. For example, compositions with solubilities as high as 5×10^{-1} moles per liter or as low as 1×10^{-5} moles per liter of tetravalent cerium, praseodymium, or terbium exhibit some corrosion resistance, although not as great as those compounds which fall within the optimum solubility range. The degree of effectiveness will depend on the particular compound itself. The solubility characteristics of the tetravalent cerium, praseodymium, or terbium in the pores of the coating can be controlled through the use of stabilizer materials, which form compounds that fall within a desired solubility range. In this way, a “controlled release” of tetravalent cerium, praseodymium, or terbium can be achieved, much as a “timed release” of hexavalent chromium is achieved in the state-of-the-art systems.

4) The “valence stabilization” helps to establish an electrostatic barrier layer around the cation-stabilizer complex in aqueous solution. The nature and character of the electrostatic double-layer surrounding the cation-stabilizer complex may be controlled and modified by careful selection of stabilizer species. Characteristics such as the electrical dipole moment and the shape/conformation (for steric effects) of the stabilizer will influence the performance of the formed inhibitor species. In general, the electrostatic double layer formed acts to protect the cation from premature reaction with hydronium, hydroxide, and other ions in solution. The formation of electrostatic barrier layers also helps to impede the passage of corrosive ions through the coating to which the rinse or seal composition was applied, to the metallic surface.

This phenomenon is exhibited in some of the hexavalent chromium systems. For example, in rinses for phosphate coatings wherein some ferricyanide is added to the hexavalent chromium, the highly charged hexavalent chromium ion is surrounded by very polar ferricyanide ions in the as-formed complexes within the pores. The orientation of the dipoles of the ferricyanide ions with respect to the highly charged chromate ion serves to attract additional layers of ions in the aqueous solution. These ions form a protective shell around the chromium ion/ferricyanide complex.

5) The as-formed tetravalent cerium, praseodymium, or terbium/valence stabilizer complex may also exhibit ion exchange behavior towards alkali species. This optional consideration is important because alkali ions (especially sodium) are notoriously corrosive towards alloys which contain metals such as aluminum, zinc, or magnesium. The hexavalent chromium-ferricyanide complex formed in some rinse formulations also exhibits this ion exchange phenomenon. The corrosion resistance of a number of phosphated steel and anodized aluminum alloys as tested using both ASTM B-117 and ASTM G-85 has been enhanced through the use of tetravalent cerium, praseodymium, or terbium species. Their corrosion resistance is comparable to that of hexavalent chromium systems.

The valence stabilizers can be inorganic or organic. A multitude of organic and inorganic stabilizer materials have been used.

In one aspect, the invention comprises a mechanistic and chemical approach to the production of corrosion-resistant rinses and seals using tetravalent cerium, praseodymium, or terbium. This approach uses stabilizer materials which form compounds with tetravalent cerium, praseodymium, or terbium within the as-formed coating that are sparingly soluble in aqueous solution, typically around approximately 5×10^{-2} to 5×10^{-5} moles/liter of tetravalent cerium, praseodymium, or terbium. This solubility range provides a release of tetravalent cerium, praseodymium, or terbium from the coating at a rate sufficiently slow enough that protection will be provided for an extended period of time and fast enough to inhibit corrosion during conventional accelerated corrosion testing methods such as ASTM B-117 and G-85. Compounds that fall slightly outside of this solubility range (as high as 5×10^{-1} to as low as 1×10^{-5} moles/liter of tetravalent cerium, praseodymium, or terbium) may also prove to be effective under certain conditions. However, formed compounds that exhibit aqueous solubilities far

outside of the target range are unlikely to be effective corrosion inhibitors. The solubility of the formed tetravalent cerium, praseodymium, or terbium compounds within the pores therefore plays a significant role in the effectiveness of the formed coating. Solubility control may be achieved using organic or inorganic stabilizer materials.

5 In another aspect, the invention is the achievement of corrosion-resistant coatings derived from rinses and seals using tetravalent cerium, praseodymium, or terbium. This approach also utilizes stabilizer materials, which form compounds that exhibit dipoles so as to form electrostatic barrier layers composed of ions, such as hydronium (H_3O^+) or hydroxide (OH^-). The formation of these barrier layers through the use of stabilizer materials can be achieved
10 using organic or inorganic materials.

 In an optional aspect, the invention is the achievement of corrosion-resistant coatings derived from rinses and seals based on tetravalent cerium, praseodymium, or terbium by the use of stabilizer materials which form compounds that exhibit ion exchange behavior towards alkali ions. The formation of this ion exchange behavior can be achieved through the use of inorganic
15 or organic stabilizer materials.

 In another aspect, the invention is the achievement of corrosion-resistant coatings based on rinses or seals containing tetravalent cerium, praseodymium, or terbium that also uses optional preparative agents in conjunction with the cerium, praseodymium, or terbium to strip off some of the already-formed barrier film in the vicinity of the pores. The typical preparative
20 agents for use with tetravalent cerium, praseodymium, or terbium are fluorides and fluorine-containing chemicals. Acidic species or other halides such as chlorides, bromides, and iodides can be used, but are less effective than fluorides as preparative agents.

 Accordingly, it is an object of the present invention to provide non-toxic rinses and seals based on tetravalent cerium, praseodymium, or terbium and methods of making and using the
25 same. These and other objects and advantages of the present invention will be more fully understood from the following detailed description of the invention. It is noted that the scope of the claims is defined by the recitations therein and not by the specific discussion of features and advantages set forth in the present description.

DETAILED DESCRIPTION OF THE INVENTION

A) STARTING MATERIALS

Five general starting materials are used for the rinse and sealing baths of the present invention. These include: a cerium, praseodymium, or terbium source; a valence stabilizer
5 source; an oxidation source (optional if tetravalent cerium, praseodymium, or terbium is already present in the rinse or sealing bath); a preparative agent source (optional); and additional solubility control agents (optional). These materials may be included as neat compounds in the
rinse and sealing baths, or may be added to the baths as already-prepared solutions. Likewise, all
10 of the described constituents do not necessarily have to be included within one solution, and in some instances (e.g., additional solubility control agents) it is typical that these constituents are used separately. Further enhancements to the formed coating may be imparted through the use of additional starting materials. Foremost among these are agents to improve the lubricity or color-fastness of the coating.

15 1) Cerium, Praseodymium, or Terbium Source

a) Cerium Source

The cerium precursor compounds can be almost any cerium compound in which the
20 cerium is in either the trivalent or tetravalent oxidation state. Water-soluble precursors are typically used. Examples of inorganic trivalent cerium ("cerous") precursor compounds include, but are not restricted to: cerous nitrate, cerous sulfate, cerous perchlorate, cerous chloride, cerous fluoride, cerous bromide, cerous iodide, cerous bromate, and complex fluorides such as cerous fluosilicate, cerous fluotitanate, cerous fluozirconate, cerous fluoborate, and cerous
25 fluoaluminate. Organometallic trivalent cerium precursor compounds include, but are not limited to, cerous formate, cerous acetate, cerous propionate, cerous butyrate, cerous glycolate, cerous lactate, cerous sulfonate, cerous alkylsulfonate, cerous alkoxysulfonate, cerous aromatic sulfonate, cerous aromatoxy sulfonate, cerous sulfamate, cerous alkyl phosphates, and cerous acetylacetonate. Complex trivalent cerium precursor compounds include, but are not limited to,
30 ammonium cerous sulfate, ammonium cerous nitrate, ammonium cerous oxalate, magnesium cerous nitrate, magnesium cerous sulfate, alkali cerous nitrate, and alkali cerous sulfate.

The cerium precursor may also be a compound in which the cerium is already in the tetravalent ("ceric") oxidation state. Examples of these compounds include, but are not restricted

to: ceric chloride, ceric fluoride, ceric perchlorate, ceric sulfate, ceric nitrate, ceric acetate, ceric propionate, ceric butyrate, ammonium ceric nitrate, ammonium ceric sulfate, magnesium ceric nitrate, magnesium ceric sulfate, alkali ceric nitrate, and alkali ceric sulfate.

Insoluble trivalent or tetravalent cerium compounds may be acceptable in some coating solutions, particularly if acids are used as the preparative agent. Examples of insoluble trivalent cerium compounds include cerous carbonate, cerous phosphate, cerous sulfide, cerous fluorocarbonate, cerous benzoate, cerous oxalate, cerous malonate, cerous tartrate, cerous malate, cerous citrate, cerous thiocyanate, cerous salicylate, cerous oxide, and cerous hydroxide. Examples of insoluble tetravalent cerium precursors are ceric hydroxide species (i.e., ceric hydroxysulfate, ceric hydroxychloride, ceric hydroxynitrate, ceric hydroxyphosphate, ceric hydroxyperchlorate, and ceric hydroxyacetate) with a hydroxide content of 50% or less.

It may not be necessary to add a separate cerium source for these conversion coating solutions if a cerium-containing alloy is to be treated. The preparative agent contained within these conversion coating formulations can dissolve some of the cerium in the substrate. This will result in trivalent cerium ions being present in the coating solution. A suitable oxidizer can then oxidize the trivalent cerium to the tetravalent oxidation state during or after coating deposition.

b) Praseodymium Source

The tetravalent praseodymium ion (Pr^{+4}) is an even better oxidizing species than Ce^{+4} . It has a radius of 0.085 nanometers, carries a charge of $^{+4}$, and has a redox potential of approximately +3.2 V. However, it has a correspondingly lower stability both in and out of solution. Therefore, valence stabilization of this ion is needed in order to use it effectively in a conversion coating. The very large redox potential of Pr^{+4} makes it prone to rapid reduction, and few materials will effectively valence stabilize Pr^{+4} in a sparingly soluble complex, which make its routine application problematic. Tetravalent praseodymium can be made using chemical or electrolytic oxidation, as can trivalent praseodymium.

Praseodymium precursors can be nearly any water soluble praseodymium compound in which the praseodymium has a trivalent or tetravalent oxidation state. Water-soluble precursors are typically used. Inorganic praseodymium precursor compounds include, but are not limited to, praseodymium nitrate, praseodymium sulfate, praseodymium perchlorate, praseodymium chloride, praseodymium fluoride, praseodymium bromide, praseodymium iodide, praseodymium

bromate, and complex fluorides such as praseodymium fluosilicate, praseodymium fluotitanate, praseodymium fluozirconate, praseodymium fluoborate, and praseodymium fluoaluminate.

Organometallic praseodymium precursor compounds include, but are not limited to, praseodymium formate, praseodymium acetate, praseodymium propionate, praseodymium

- 5 lactate, praseodymium benzenesulfonate, and praseodymium acetylacetonate. Complex praseodymium precursor compounds include, but are not limited to, ammonium praseodymium sulfate, ammonium praseodymium nitrate, magnesium praseodymium nitrate, magnesium praseodymium sulfate, alkali praseodymium nitrate, and alkali praseodymium sulfate.

10 c) Terbium Source

The tetravalent terbium ion (Tb^{+4}) is an even better oxidizing species than Ce^{+4} . It has a radius of 0.076 nanometers, carries a charge of $^{+4}$, and has a redox potential of approximately +3.2 V. However, it has a correspondingly lower stability both in and out of solution.

- Therefore, valence stabilization of this ion is needed in order to use it effectively in a conversion
15 coating. The very large redox potential of Tb^{+4} makes it prone to rapid reduction, and few materials will effectively valence stabilize Tb^{+4} in a sparingly soluble complex, which make its routine application problematic. Tetravalent terbium can be made using chemical or electrolytic oxidation, as can trivalent terbium.

- Terbium precursors can be nearly any water soluble terbium compound in which the
20 terbium has a trivalent or tetravalent oxidation state. Water-soluble precursors are typically used. Inorganic terbium precursor compounds include, but are not limited to, terbium nitrate, terbium sulfate, terbium perchlorate, terbium chloride, terbium fluoride, terbium bromide, terbium iodide, terbium bromate, and complex fluorides such as terbium fluosilicate, terbium fluotitanate, terbium fluozirconate, terbium fluoborate, and terbium fluoaluminate.
- 25 Organometallic terbium precursor compounds include, but are not limited to, terbium formate, terbium acetate, terbium propionate, terbium lactate, terbium benzenesulfonate, and terbium acetylacetonate. Complex terbium precursor compounds include, but are not limited to, ammonium terbium sulfate, ammonium terbium nitrate, magnesium terbium nitrate, magnesium terbium sulfate, alkali terbium nitrate, and alkali terbium sulfate.

30

d) Mixed Cerium, Praseodymium, and Terbium Sources

It is also possible to use mixtures of cerium, praseodymium, and/or terbium sources as feedstock for material preparation. Inclusion of other rare earths (such as yttrium, lanthanum, or neodymium) that cannot be oxidized to the tetravalent state is also permissible. Additionally,

5 minerals that serve as ores for rare earths are ideal source materials for this application. For example, sulfuric acid is often applied to rare earth ores to separate the rare earth mixtures (REM) from native rock. If these sulfuric acid extracts were in turn to be supplied with oxidizers and valence stabilizers, source material for this application is achieved. Examples of rare earth-containing minerals suitable for this application are bastnaesite $[(\text{REM})\text{CO}_3\text{F}]$, monazite
10 $[(\text{REM})\text{PO}_4]$, xenotime $[(\text{REM})\text{PO}_4]$, loparite $[(\text{REM},\text{Na},\text{Ca})(\text{Ti},\text{Nb})\text{O}_3]$, lanthanite $[(\text{REM})_2(\text{CO}_3)_3]$, rhabdophane $[(\text{REM})\text{PO}_4]$, fergusonite $[(\text{REM})\text{NbO}_4]$, cebaite $[\text{Ba}_3(\text{REM})_2(\text{CO}_3)_5\text{F}_2]$, aeschynite $[(\text{Ca},\text{REM})(\text{Ti},\text{Nb})(\text{O},\text{OH})_6]$, lucasite $[(\text{REM})\text{Ti}_2(\text{O},\text{OH})_6]$, stillwellite $[(\text{REM},\text{Ca})\text{BSiO}_5]$, samarskite $[(\text{REM},\text{Fe})_3(\text{Nb},\text{Ta},\text{Ti})_5\text{O}_{16}]$, parisite $[\text{Ca}(\text{REM})_2(\text{CO}_3)_3\text{F}_2]$, gadolinite $[\text{Be}_2\text{Fe}(\text{REM})_2\text{Si}_2\text{O}_{10}]$, fluocerite $[(\text{REM})\text{F}_3]$, cerianite
15 $[(\text{REM})\text{O}_{2-3}]$, churchite $[(\text{REM})\text{PO}_4]$, or combinations thereof.

2) Valence Stabilizers

Corrosion resistance comparable to that of hexavalent chromium can be achieved by the use of valence stabilized tetravalent cerium, praseodymium, or terbium ions in the rinse or
20 sealing baths. Valence stabilization has not been recognized previously as an important consideration in the development of effective corrosion-inhibiting rinses and seals. A variety of inorganic and organic stabilizers are available that can control such properties as solubility, mobility, ion exchange, and binder compatibility. The stabilizer complex can also act as an ion-exchange host and/or trap for alkali or halide ions in solution.

25 Cerium, praseodymium, and/or terbium are effective as oxidative corrosion inhibitors if they can be supplied in sufficient quantities in the tetravalent charge state when brought into contact with unprotected bare metal. The Ce^{+4} ionic radius of 87 picometers is larger than the 44 picometers of the hexavalent chromium ion, and so it will have a correspondingly lower charge density (electrostatic field) per ion. The Pr^{+4} and Tb^{+4} ionic radii of 85 and 76 picometers,
30 respectively, are comparable in size.

As noted in the Summary of the Invention, the valence stabilizer may serve one or more important functions in the establishment of a successful rinse or sealing solution. First, the valence stabilizer, when used with tetravalent cerium, praseodymium, or terbium, results in a “sparingly soluble” Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complex. Although the exact

5 solubility of this complex can be slightly modified through the incorporation of different cations or anions (either through the dissolution of the coated metal, or by additional solubility control agents), appreciable corrosion inhibition will be observed if the tetravalent cerium, praseodymium, or terbium is incorporated in the coating enhanced via rinsing or sealing as a Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer complex that exhibits a solubility in water of between about 5×10^{-5} moles per liter and about 5×10^{-2} moles per liter of available Ce^{+4} , Pr^{+4} , or Tb^{+4} . Therefore,

10 any material (inorganic or organic) in the coating bath that complexes with tetravalent cerium, praseodymium, or terbium and results in the formation of a Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -containing complex, which exhibits solubilities within or near this solubility range, can serve as a valence stabilizer for tetravalent cerium, praseodymium, or terbium.

15 Rinse or sealing solutions that contain valence stabilizers that result in the formation of stabilized cerium, praseodymium, or terbium compounds that fall outside of this particular solubility range may exhibit some degree of corrosion inhibition and may be effective under certain circumstances. Although not as effective as those compounds within the optimum solubility range, compositions with solubilities as high as about 5×10^{-1} moles per liter or as low

20 as about 1×10^{-5} moles per liter of tetravalent cerium, praseodymium, or terbium at standard temperature and pressure (about 25°C and about 760 Torr) exhibited some corrosion resistance. For example, in situations where the substrate metal pieces are exposed to environments which require much more immediate corrosion exposure (e.g., sudden immersion in seawater), adequate corrosion protection can be achieved through the formation of a tetravalent cerium,

25 praseodymium, or terbium compound which exhibits a higher solubility in water (e.g., 5×10^{-1} to 5×10^{-3} moles/liter tetravalent cerium, praseodymium, or terbium). In this way, a more “immediate” release of protective cerium, praseodymium, or terbium ions can be achieved, although the tetravalent cerium, praseodymium, or terbium will be depleted faster from the coating. Tetravalent cerium, praseodymium, or terbium solubilities that are lower than this

30 optimum range (e.g., 1×10^{-5} to 1×10^{-3} moles/liter of tetravalent cerium, praseodymium, or terbium) may be desirable for some situations (e.g., in nearly pure water with low aeration rates).

However, compounds that exhibit solubilities far outside the target range are unlikely to be effective corrosion inhibitors.

The solubility characteristics of the tetravalent cerium, praseodymium, or terbium in the rinsed or sealed coatings are controlled with stabilizer materials that form compounds within the desired solubility range. The exact solubility will be strongly dependent on the application of the rinse or sealing solutions, the nature of the barrier film being treated, and the net aqueous solubility of the overlying paints and coatings.

The formation of coatings with the proper release rate of Ce^{+4} , Pr^{+4} , or Tb^{+4} ions is problematic because of the instability of Ce^{+4} and especially Pr^{+4} or Tb^{+4} out of solution.

- 10 Tetravalent cerium compounds such as acetate, sulfate, ammonium ceric nitrate, and ammonium ceric sulfate are generally too soluble to serve as effective corrosion inhibitors if formed from a rinse or seal solution. Oxides and hydroxides of Ce^{+4} , Pr^{+4} , or Tb^{+4} are much too insoluble in water to serve effectively as corrosion inhibitors in a coating. For example, ceric oxide (CeO_2) is so insoluble that its solubility has never been accurately determined. The more soluble
- 15 “hydrated” ceric oxide (ceric hydroxide – $\text{Ce}(\text{OH})_4$) is reported to exhibit a solubility product in water between 4.2×10^{-51} and 1.5×10^{-51} , resulting in a cerium solubility of approximately 5×10^{-12} moles/liter Ce^{+4} (see Tarayan, V. M. and Eliazyan, L. A., *Izvest. Akad. Nauk Armyan. S.S.R., Ser. Khim. Nauk* 10: 189-93, (1957) in *General and Physical Chemistry*, vol. 2, col. 9722 (1958) (Abstract)). Similarly, tetravalent praseodymium oxide (Pr_6O_{11}) is reported to exhibit
- 20 solubility in water of 6.5×10^{-7} moles/liter Pr^{+4} (see Busch, W., *Z. anorg. allgem. Chem.* 161: 161-79 (1927) in *Chemical Abstracts*, vol. 21, p. 2412 (Abstract)). For these low solubility compounds, the release rates of Ce^{+4} or Pr^{+4} are too low to compare adequately to Cr^{+6} from the state-of-the-art coatings.

- One method of providing a useful source of tetravalent cerium, praseodymium, or
- 25 terbium at a metal surface is the creation of a sparingly soluble compound in which the Ce^{+4} , Pr^{+4} , or Tb^{+4} is shielded from premature reduction during and after compound formation during the rinsing or sealing treatments. The assembly of a protective shell around the highly charged Ce^{+4} , Pr^{+4} , or Tb^{+4} and its associated oxygen and hydroxyl species can help control the rate at which the cerium, praseodymium, or terbium is reduced and its oxygen is released. Proper
- 30 selection of materials for forming the protective shell will allow solubility tailoring of the entire

assembly to its intended application environment. Valence stabilizers are materials that, when assembled, modify the rate of reduction and solubility of the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion.

The electrostatic character of the complex should also be considered in order to create a Ce^{+4} , Pr^{+4} , or Tb^{+4} stabilizer complex with optimal corrosion resistance. Valence stabilizers may
5 also contribute to the development of a substantial electrostatic double layer. An electrostatic double layer of polar or charged species such as hydronium (H_3O^+) or hydroxide (OH^-) ions surrounding the stabilized cerium, praseodymium, or terbium complex will help control cerium, praseodymium, or terbium reduction and solubility and enhance the barrier properties of the treated coating. Valence stabilizers which form sparingly soluble cerium, praseodymium, or
10 terbium complexes with enhanced electrostatic double layers will maximize the corrosion-inhibiting character of the rinsed or sealed coating.

The tetravalent cerium, praseodymium, or terbium ions are larger than the hexavalent chromium ion, with less charge density over the surface of the ions. Therefore, the valence stabilizers for Ce^{+4} , Pr^{+4} , or Tb^{+4} must be more efficient in the establishment of dipole moments
15 than the valence stabilizers typically used for hexavalent chromium so that comparable corrosion resistance can be achieved in relation to the state-of-the-art Cr^{+6} compositions. Valence stabilizers which have a comparable dipole moment to the Cr^{+6} stabilizers, or which exhibit even less of a dipole moment than the Cr^{+6} stabilizers can also function as valence stabilizers, but the resultant corrosion resistance of the treated coatings will, in all probability, be less than for the
20 current commercial hexavalent chromium-based rinses and seals.

Large spheres of hydration around corrosion inhibitors can act as electrostatic and physical barriers to the passage of large corrosive ions such as Cl^- and SO_4^{2-} through the coating to the metal surface. The size of the electrostatic double layer is a function of the electrostatic potential at the complex surface and is inversely proportional to the ionic strength of the
25 surrounding solution. Compounds that can carry a charge, have a natural electrostatic dipole, or can have a dipole induced, will likely form an electrostatic double layer in aqueous solution. However, these compounds do not normally act as corrosion inhibitors because they have not been optimized for that purpose.

These facts are relevant when tetravalent cerium's propensity for attracting hydroxide
30 species such as OH^- in solution is considered. While a tetravalent cerium ion surrounded solely by OH^- (i.e., $\text{Ce}(\text{OH})_4$) may have a slight degree of aqueous solubility, the much lower charge

density (electrostatic field) that is exhibited by Ce^{+4} (coupled with the muting effect of the surrounding OH^- ions) implies that the electrostatic double layer formed around this assemblage will be small. If fewer hydroxide species surround the tetravalent cerium ion (i.e., $\text{Ce}(\text{OH})_2^{2+}$ or $\text{Ce}(\text{OH})^{3+}$), the electrostatic double layer around these ionic assemblages is increased, which will
5 result in increased corrosion protection. Tetravalent cerium surrounded by no hydroxide species offers the highest degree of corrosion protection.

A simple laboratory experiment confirms this effect. If tetravalent cerium hydroxide ($\text{Ce}(\text{OH})_4$) is placed into deionized water of pH 7, only a minor pH change will be observed, implying that the ionic attraction of this species for hydronium or hydroxide species is minimal.
10 However, if icosahedral $\text{Ce}(\text{NO}_3)_6^{2-}$ (note that this ion contains no hydroxide) is placed into deionized water of pH 7, a quite remarkable pH drop to -1 can be observed. The released tetravalent cerium ions will scavenge virtually all of the available OH^- ions in solution (possibly even degrading H_2O itself to obtain OH^-), resulting in this dramatic pH drop.

These factors account for the lower corrosion performance of the hydrous oxides and
15 hydroxides formed in many of the prior art references. Because the electrostatic double layers of hydrated cerium oxides and hydroxides are so small, their ability to impede the progress of corroding species is very low, even in the event that a minor concentration of these complexes become soluble. Unlike other known corrosion-resistant compounds described in the art, which extol the formation of hydrous cerium oxides and hydroxides, this invention recognizes that
20 these species result in lower corrosion performance in side-by-side tests. In fact, any oxo- or hydroxo- coordination greater than 50% on the tetravalent cerium ions (i.e., greater than $\text{Ce}(\text{OH})_2^{2+}$ or CeO^{2+}) is objectionable. It is also for this reason that this invention does not promote the use of hydroxide or oxide precursors as cerium sources.

Optionally, the incorporation of the valence stabilizer (inorganic or organic) may result in
25 the formation of a Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer compound that also exhibits ion exchange behavior towards alkali ions. As noted in the Summary of the Invention, this is not a requirement of the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complex, but it is a desirable characteristic for enhanced corrosion resistance. Some existing state-of-the-art chromium systems exhibit this phenomenon, but complexes derived from rinse or sealing solutions that do
30 not exhibit this phenomenon have been successfully demonstrated to inhibit corrosive attack.

Rare earth coordination chemistry, which has been the subject of numerous scientific studies for almost 100 years, identifies chemical binding preferences, structure stability, and physical properties of the resulting compounds. Producing effective Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complexes requires understanding the electrostatic and structural influence of candidate species on the complex. Stabilizers can be designed that result in cerium, praseodymium, or terbium compounds with the necessary physical, electrical, and chemical properties to form corrosion inhibitors with this information. Property tailoring can also take place through selection of specific anions or cations bound to the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer coordination complex.

The functional anatomy of inorganic stabilizers is simple because of the limited number of atoms and structural arrangements involved in their formation. The anatomy of organic stabilizers is not as simple. An organically stabilized cerium, praseodymium, or terbium complex may have one or more organic ligands that may have one or more bonding sites that can interact with the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion/oxide cluster. The bonding groups can be the same or different atoms or functional groups on an individual or a variety of ligands. An organic stabilizer can be modified in an unlimited number of ways to tailor its physical behavior with respect to such properties as chemical reactivity, solubility, electrostatic and polar character, and functional behavior.

The stability of the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complex is strongly influenced by the charge, polarity, and degree of polarizability of specific binding sites. Factors influencing compound stability include: 1) ion-pair interactions for charged ligands and Ce^{+4} , Pr^{+4} , or Tb^{+4} ; 2) ion-dipole and ion-induced dipole interactions for neutral ligands; 3) hydrogen bonding; and 4) the hard-soft acid-base (HSAB) rules convention of coordination chemistry. HSAB rules help identify functional groups on ligands that might be effective as binding sites. Optimum binding for organic valence stabilizers to Ce^{+4} , Pr^{+4} , or Tb^{+4} will involve ligands with hard bonding species such as those that contain oxygen or nitrogen. Certain coordination complexes of the soft bases sulfur and phosphorus are also effective for binding with Ce^{+4} , Pr^{+4} , or Tb^{+4} . HSAB rules can also help identify groups that might provide a degree of polarization to the stabilizer because of their large dipole moments.

The nature of bonding between the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion/oxide cluster and the stabilizer ligand can be altered by using a substituent group to modify the stabilizer. Specific interactions

between the ligand and Ce^{+4} , Pr^{+4} , or Tb^{+4} can be tailored by substituent group selection, coupled with altering the size or geometry of the complexing ligand. For example, some substituent groups have large dipole moments associated with them, which will increase the electrostatic barrier layers associated with the cerium, praseodymium, or terbium/valence stabilizer

5 complexes. These include: ketones ($=\text{C}=\text{O}$), thioketones ($=\text{C}=\text{S}$), amides ($-\text{C}[\text{=O}]-\text{NR}_2$), thioamides ($-\text{C}[\text{=S}]-\text{NR}_2$), nitriles or cyano groups ($-\text{CN}$), isocyanides ($-\text{NC}$), nitroso groups ($-\text{N}=\text{O}$), thionitroso groups ($-\text{N}=\text{S}$), nitro groups ($-\text{NO}_2$), azido groups ($-\text{N}_3$), cyanamide or cyanonitrene groups ($=\text{N}-\text{CN}$), cyanate groups ($-\text{O}-\text{CN}$), isocyanate groups ($-\text{N}=\text{C}=\text{O}$), thiocyanate groups ($-\text{S}-\text{CN}$), isothiocyanate groups ($-\text{N}=\text{C}=\text{S}$), nitrosamine groups ($=\text{N}-\text{N}=\text{O}$),

10 thionitrosamine groups ($=\text{N}-\text{N}=\text{S}$), nitramine groups ($=\text{N}-\text{NO}_2$), thionitramine groups ($=\text{N}-\text{NS}_2$), carbonylnitrene groups ($-\text{CO}-\text{N}$), thiocarbonylnitrene groups ($-\text{CS}-\text{N}$), sulfenyl halides ($-\text{S}-\text{X}$), sulfoxides ($=\text{S}=\text{O}$), sulfones ($=\text{S}[\text{=O}]_2$), sulfinyl groups ($-\text{N}=\text{S}=\text{O}$), thiosulfinyl groups ($-\text{N}=\text{S}=\text{S}$), sulfenyl thiocyanato groups ($-\text{S}-\text{S}-\text{CN}$), sulfenyl cyanato groups ($-\text{S}-\text{O}-\text{CN}$), sulfodiimine groups ($=\text{S}[\text{=NH}]_2$), sulfur dihaloimido groups ($-\text{N}=\text{SX}_2$), sulfur oxide dihaloimido

15 groups ($-\text{N}=\text{S}[\text{=O}]\text{X}_2$), aminosulfur oxide trihalide groups ($=\text{N}-\text{S}[\text{=O}]\text{X}_3$), sulfonyl azide groups ($-\text{S}[\text{=O}]_2\text{N}_3$), sulfonyl thiocyanate groups ($-\text{S}[\text{=O}]_2\text{SCN}$), sulfonyl cyanate groups ($-\text{S}[\text{=O}]_2\text{OCN}$), sulfonyl cyanide groups ($-\text{S}[\text{=O}]_2\text{CN}$), halosulfonate groups ($-\text{S}[\text{=O}]_2\text{OX}$), phosphonyl thiocyanate groups ($-\text{P}[\text{=O}]\text{OHSCN}$), phosphonyl cyanate groups ($-\text{P}[\text{=O}]\text{OHOCN}$), and phosphonyl cyanide groups ($-\text{P}[\text{=O}]\text{OHCN}$). The polarization of the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -

20 stabilizer can therefore be optimized via evaluation of the effect of ligand type and substituents. The influence of the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion on the aqueous solution outside of, or external to, the valence stabilizer shell (or hydration sphere) may play an important role in the complexation properties of a given ligand. The electrostatic action of the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion on the aqueous solution will also control the diameter of the hydration shell around the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -

25 stabilizer complex.

The number of binding sites available on the complexing ligand is important to the resulting Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer's properties. Several ligands are necessary to stabilize Ce^{+4} , Pr^{+4} , or Tb^{+4} effectively if the chosen ligand has only one binding site. Six NO_3^- ligands are needed to icosahedrally coordinate Ce^{+4} in the hexanitratocerate (IV) complex because NO_3^-

30 has only one binding site. Bulky ligands with only one binding site, like pyridine, can be sterically hindered from packing tightly around the ion, which will result in decreased complex

stability. Conversely, macrocyclic organic and polymeric inorganic ligands may have many suitable binding sites. However, instability will result if a Ce^{+4} , Pr^{+4} , or Tb^{+4} ion is not completely embraced by all of the multiple macromolecular bonding sites on the ligand. For example, if a macromolecule surrounding the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion has an insufficient number of binding sites available for charge balance, then the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer complex formed will be much less stable than with a macromolecule that contains an adequate number of sites.

The physical geometry of the binding sites is also important to the stability of the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer complex. The influence of site geometry becomes evident when the solvation shell of a Ce^{+4} , Pr^{+4} , or Tb^{+4} ion is replaced by the ligand donor atoms, as when rinse or sealing solutions are applied. The number of available ligand binding sites should be at least equal to the standard coordination number of the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion. The balance between solvation of the ligand and Ce^{+4} , Pr^{+4} , or Tb^{+4} and their complexation where Ce^{+4} , Pr^{+4} , or Tb^{+4} is solvated by a specific ligand is one factor in maintaining stability. Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -ligand attraction increases with the number of binding sites on the ligand. However, with increasing number of binding sites, site-site repulsions will also increase, resulting in lower stability.

The Ce^{+4} , Pr^{+4} , or Tb^{+4} ions generally favor complexation in the icosahedral (coordination number 12) or octahedral (coordination number 6) arrangements. However, these ions will occasionally be found in a cubic, square antiprismatic, or complex arrangement. Valence stabilizers (and stabilizer combinations) should be selected with the goal of achieving these coordinations.

Inorganic materials that tend to “polymerize” and form octahedra or icosahedra (or a combination thereof) around ions such as Ce^{+4} , Pr^{+4} , or Tb^{+4} are termed isopolyanions, and their resultant complexes with Ce^{+4} , Pr^{+4} , or Tb^{+4} are termed heteropolyanions or heteropolymetallates. This polymerization of the inorganic valence stabilizer species results in stacks of octahedra or icosahedra with central cavities, which can accommodate at least one Ce^{+4} , Pr^{+4} , or Tb^{+4} ion, thereby stabilizing it.

Valence stabilizers and combinations of stabilizers can be manipulated by the selection of “shaping groups” and heteroatoms positioned at the binding site. Inorganic valence stabilizers are typically oxygen-containing coordination compounds. Saturated organic chains can form flexible ligands that wrap around Ce^{+4} , Pr^{+4} , or Tb^{+4} and can enhance their stability. Unsaturated

organics typically have less freedom to bend and contort and are less likely to be able to wrap around the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion. The addition of substituents onto an organic ligand may further restrict its freedom to flex.

The actual size of the valence stabilizer complex situated around the Ce^{+4} , Pr^{+4} , or Tb^{+4} ion has an important role in solubility control. Solubility of the complex scales roughly with the inverse of its physical diameter. Ce^{+4} , Pr^{+4} , or Tb^{+4} and their layer of negatively charged hydroxyl ions is very small and results in their high degree of aqueous solubility. The field strength of the complex also scales with the inverse of its physical diameter. Large complexes with an optimal degree of solubility will not necessarily be ideal with respect to the size of the electrostatic double layer. The size of the ligand is therefore balanced against the desired electrical properties.

The addition (or subtraction) of functional groups on organic valence stabilizers can be used to modify the solubility of the formed Ce^{+4} , Pr^{+4} , or Tb^{+4} /valence stabilizer species. For example, the addition of sulfonated groups ($-\text{SO}_3^-$) to organic valence stabilizers will significantly increase the solubility in water. Other substituent groups that will increase the solubility in water include: carboxyl groups ($-\text{CO}_2^-$), hydroxyl groups ($-\text{OH}$), ester groups ($-\text{CO}_3^-$), carbonyl groups ($=\text{C}=\text{O}$), amine groups ($-\text{NH}_2$), nitrosamine groups ($=\text{N}-\text{N}=\text{O}$), carbonylnitrene groups ($-\text{CO}-\text{N}$), sulfoxide groups ($=\text{S}=\text{O}$), sulfone groups ($=\text{S}[\text{=O}]_2$), sulfinyl groups ($-\text{N}=\text{S}=\text{O}$), sulfodiimines ($=\text{S}[\text{=NH}]_2$), sulfonyl halide groups ($-\text{S}[\text{=O}]_2\text{X}$), sulfonamide groups ($-\text{S}[\text{=O}]_2\text{NH}_2$), monohalosulfonamide groups ($-\text{S}[\text{=O}]_2\text{NHX}$), dihalosulfonamide groups ($-\text{S}[\text{=O}]_2\text{MX}_2$), halosulfonate groups ($-\text{S}[\text{=O}]_2\text{OX}$), halosulfonate amide groups ($=\text{N}-\text{S}[\text{=O}]_2\text{X}$), aminosulfonate groups ($=\text{N}-\text{S}[\text{=O}]_2\text{OH}$), iminodisulfonate groups ($-\text{N}[\text{SO}_3^-]_2$), phosphonate groups ($-\text{PO}_3^{-2}$), phosphonamide groups ($-\text{PO}_2\text{NH}_2^-$), phosphondiamide groups ($-\text{PO}[\text{NH}_2]_2$), aminophosphonate groups ($=\text{N}-\text{PO}_3^{-2}$), and iminodiphosphonate groups ($-\text{N}[\text{PO}_3^{-2}]_2$). Conversely, addition of nitro groups ($-\text{NO}_2$), perfluoroalkyl groups ($-\text{C}_x\text{F}_{2x+1}$), perchloroalkyl groups ($-\text{C}_x\text{Cl}_{2x+1}$), nitramine groups ($=\text{N}-\text{NO}_2$), thioketone groups ($=\text{C}=\text{S}$), sulfenyl halide groups ($-\text{S}-\text{X}$), or sulfur dihaloimide groups ($-\text{N}=\text{SX}_2$) to an organic valence stabilizer will lower its solubility in water. In this way, the solubility characteristics of valence stabilizers can be “tailored” to meet specific needs.

The physical, chemical, and electrostatic requirements for the design of effective Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer complexes result in lists of stabilizers that may be divided into wide band

or narrow band stabilizer classes. The compounds listed here are general guides for the initial selection of a coordination compound and do not represent a complete or final list. New organic and inorganic compounds are continuously being developed, compound toxicity limits can change, and some currently available compounds may have been overlooked. Tailoring

5 substituent groups and the selection of cations or anions for charge balance can influence whether a particular Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer complex will have a wide band or narrow band character.

Valence stabilizers for tetravalent cerium, praseodymium, or terbium that embody the desirable characteristics of stabilizers as described above are typical when designing a rinse or seal solution for maximum effectiveness. These “wide band” stabilizers result in the formation of compounds that provide significant corrosion resistance when used with tetravalent cerium, praseodymium, or terbium. Less typical valence stabilizers (“narrow band”) result in satisfactory corrosion inhibition only under limited applications. Wide band rinse or sealing solutions for general purpose applications and narrow band derivatives for specific uses have been identified and developed. Wide band behavior (stability, solubility, and polarization) can be achieved by both inorganic and organic valence stabilizers, as can ion exchange capability.

In general, valence stabilizers that form cerium, praseodymium, or terbium complexes, which exhibit the necessary physical properties of stability, solubility, and polarization, may be achieved with both inorganic and organic valence stabilizers. Ion exchange behavior can also be achieved with both inorganic and organic coordination compounds.

2a) Wide Band Inorganic Valence Stabilizers for Tetravalent Cerium

Wide band inorganic valence stabilizers are formed around the Ce^{+4} ion by polymerizing in the rinse or sealing solution near the barrier layer/substrate metal surface being treated. Acidic solutions can become basic near the work piece surface (and especially within the pores in the treated barrier film) where precipitation of the cerium- or praseodymium-stabilizer complex occurs during the rinsing or sealing process. Inorganic wide band valence stabilizers for Ce^{+4} include, but are not limited to: molybdates (Mo^{+6} , Mo^{+5} , or Mo^{+4} , for example $[Ce^{+4}Mo_{12}O_{42}]^{8-}$, $[Ce^{+4}Mo_7O_{24}]^{2-}$, and $[Ce^{+4}_2Mo_{14}O_{48}]^{4-}$); tungstates (W^{+6} , W^{+5} , or W^{+4} , for example $[Ce^{+4}W_{12}O_{42}]^{8-}$, $[Ce^{+4}W_8O_{28}]^{4-}$, and $[Ce^{+4}W_{10}O_{35}]^{6-}$); vanadates (V^{+5} or V^{+4} , for example $[Ce^{+4}V_{18}O_{51}]^{8-}$); niobates (Nb^{+5} or Nb^{+4} , for example $[Ce^{+4}Nb_2O_6(OH)_4]^{2-}$); tantalates (Ta^{+5} or

Ta⁺⁴, for example [Ce⁺⁴Ta₂O₆(OH)₄]²⁻; tellurates (Te⁺⁶ or Te⁺⁴, for example Ce⁺⁴(TeO₄)₂); periodates (I⁺⁷, for example [Ce⁺⁴IO₆]¹⁻); iodates (I⁺⁵, for example Ce⁺⁴(IO₃)₄); carbonates (C⁺⁴, for example [Ce⁺⁴(CO₃)₅]⁶⁻); antimonates (Sb⁺⁵ or Sb⁺³); stannates (Sn⁺⁴); phosphates (P⁺⁵, for example Ce⁺⁴₃(PO₄)₄, Ce⁺⁴(HPO₄)₂, Ce⁺⁴P₂O₇, and [Ce⁺⁴(P₂O₇)₂]⁴⁻); nitrates (N⁺⁵, for example
5 [Ce⁺⁴(NO₃)₆]²⁻); bromates (Br⁺⁵, for example Ce⁺⁴(BrO₃)₄); and sulfates (S⁺⁶, for example [Ce⁺⁴(SO₄)₄]⁴⁻). Many of these inorganics form octahedral and icosahedral structures on precipitation from solution. For example, tellurate ions begin to polymerize in solution near pH 5 and will complex with Ce⁺⁴ ions near the work piece or within the treated barrier film pores as solution pH increases. The exact chemical nature of these valence stabilizers (i.e., chemical
10 formulation and valence state of the atom in the center of the icosahedra or octahedra) is highly dependent upon the specific pH and redox conditions.

The stability of the heteropolymetallates is a function of composition and structure. The relatively unstable Ce⁺⁴ ion is protected and stabilized within the surrounding octahedral and icosahedral groups, although specific configurations of the heteropolymetallate anions differ
15 from stabilizer to stabilizer (i.e., from molybdate to periodate to carbonate).

The dimensions of the octahedra and icosahedra are controlled by the size of the heteroatom (e.g., Mo, W, Te) around which they are assembled. A Ce⁺⁴ ion trapped by the precipitation of these heteropolymetallates and its resulting "ion within a cage" structure can exhibit an even greater apparent volume due to the development of a large electrostatic double
20 layer. This will influence both the valence stabilization of the Ce⁺⁴ as well as the solubility of the assembled complex. These compounds are also reported to be excellent ion exchange agents for alkali ions.

This caging structure serves to lower the solubility of the Ce⁺⁴ because the chemical elements typically associated with many of these valence stabilizers (e.g., I, Te, Mo, W) are all
25 inherently less soluble in water than Ce⁺⁴. These materials can also establish oriented dipoles with the interior Ce⁺⁴ ion, thereby forming the desired barrier layers (e.g., of hydronium ions), much as ferricyanide or molybdate contributes to some hexavalent chrome systems. Finally, the elements associated with these valence stabilizers themselves can contain high valence ions, such as V⁺⁵, Te⁺⁶, or Mo⁺⁶, which will also serve somewhat in corrosion protection, although not to
30 the degree of Ce⁺⁴, due to their lower redox potential.

Water-soluble precursors for the formation of these valence stabilizers are desirable in order to ensure that sufficient material is available for coating deposition from aqueous solutions. Identification of suitable water-soluble precursors may be difficult, since many of the elements associated with these valence stabilizers (e.g., Mo, W, Te, etc.) do not typically form water-soluble compounds (hence, their beneficial use as a valence stabilizer). Representative examples of suitable precursors for “wide band” inorganic valence stabilizers are listed in Table 5.

The solubilities given in Table 5 are usually for the simplest salts of each compound. More complex, partially “polymerized” salts for each compound (e.g., para- or meta-polymorphs) can also be used as precursors, although these polymorphs typically exhibit slightly lower solubilities in water than the simple salts. Peroxo-salts of these compounds, especially percarbonates, permolybdates, pertungstates, and pervanadates can also be utilized as precursors. Formation of the chosen heteropolymetallates from precursors such as the fluorides, chlorides, bromides, nitrates, and perchlorates (e.g., SnCl_4 to form heterostannates, SbF_5 to form heteroantimonates, etc.) proved to be difficult, but may be acceptable under certain circumstances.

Ce^{+4} stabilized with a heteropolymolybdate complex is an example of a wide band inorganically stabilized cerium complex. This complex is very stable and provides significant corrosion protection when it is formed from a rinsing or sealing solution. The size of the cavity developed at the center of a ligand with three or more bonding sites is important. A cavity that is too large or too small will tend to be less stable and less effective as a corrosion inhibitor.

The valence stabilizer can be a cross between two or more of the wide-band inorganic valence stabilizers listed above. For example, in some instances it may be desirable to form a valence stabilizer out of a periodate and a molybdate. During the coating process, both of these materials will polymerize to form a mixed periodate/molybdate valence stabilizer out of the rinsing or sealing solution.

2b) Wide Band Organic Valence Stabilizers for Tetravalent Cerium

A variety of organic compounds meet the criteria to be typical valence stabilizers for Ce^{+4} . These coordination ligands produce Ce^{+4} valence stabilized complexes, which fulfill the general requirements of a Ce^{+4} rinse or seal inhibitor material. Organic compounds can be very effective cerium stabilizers and provide the greatest degree of freedom in designing new

stabilizer species with new functionalities. There are many more possible organic valence stabilizer species than inorganic valence stabilizers because of the large number of organic compounds and functionalities which exist. Some of the typical organic valence stabilizer species are listed in Table 2 below.

- 5 The number of wide band (and narrow band) organic compounds that are acceptable as valence stabilizers for tetravalent cerium is limited. Common organic compounds such as alcohols, aldehydes, ketones, esters, ethers, alkyl or aromatic halides, most carboxylic acids, anhydrides, phenols, sulfonic acids, phosphonic acids, carbohydrates, waxes, fats, sugars, and oils are not as effective as the structural types described in these Tables to stabilize the
- 10 tetravalent cerium ion. At best, some of the organic types described in the Tables herein may presently be used for other industrial applications, but their incorporation into corrosion-inhibiting blends to stabilize tetravalent cerium has heretofore been unrecognized.

 The choice of substituent functional groups on these general classes of valence stabilizers will affect the physicochemical properties of the Ce^{+4} -containing complex and the corrosion

15 resistance achieved using that complex. For example, the addition of $-NH_2$ or $=O$ substituents increases the net polarization of the overall Ce^{+4} -valence stabilizer complex, but this will also increase its water solubility. Careful molecular design of Ce^{+4} complexes is necessary to achieve desired performance characteristics.

 In general, the bonding atoms in typical organic valence stabilizers are oxygen or

20 nitrogen, with sulfur or phosphorus being acceptable in some circumstances. Sulfur or phosphorus are complexed with Ce^{+4} most frequently in association with oxygen. Bonding atoms such as carbon, silicon, tin, arsenic, selenium, and antimony are much less desirable due to problems with valence stability, toxicity, or solubility. These valence stabilizers all serve to stabilize the Ce^{+4} ion within a sparingly soluble complex that can exhibit a polar character in

25 aqueous solution.

Table 2. Wide Band Organic Valence Stabilizers for the Ce⁺⁴ Ion

General Structural Name (Type of Organic)	Structural Representation
N Valence Stabilizer #1: Monoamines (N Monodentates)	NH ₃ , NH ₂ R, NHR ₂ , and NR ₃ where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N Valence Stabilizer #2: Diamines (N-N Bidentates)	R'-N-R-N-R'', where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N Valence Stabilizer #3: Triamines (either N-N Bidentates or N-N Tridentates)	R-N-R'-N-R''-N-R''', where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N Valence Stabilizer #4: Tetramines (N-N Bidentates, N-N Tridentates, or N-N Tetracentates)	R-N-R'-N-R''-N-R'''-N-R''''-N-R''''', where R, R', R'', R''', and R'''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N Valence Stabilizer #5: Pentamines (N-N Bidentates, N-N Tridentates, or N-N Tetracentates)	R-N-R'-N-R''-N-R'''-N-R''''-N-R''''', where R, R', R'', R''', R'''', and R''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N Valence Stabilizer #6: Hexamines (N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexadentates)	R-N-R'-N-R''-N-R'''-N-R''''-N-R'''''-N-R''''''-N-R''''''', where R, R', R'', R''', R'''', R''''', and R'''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

	from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #7:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms wherein at least one Nitrogen Atom is a Binding Site (N Monodentates or N-N Bidentates)	Five membered heterocyclic ring containing one, two, three, or four nitrogen atoms, all of which may or may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, or P atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #8:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms wherein at least one Nitrogen Atom is a Binding Site (N Monodentates or N-N Bidentates)	Six membered heterocyclic ring containing one, two, three, or four nitrogen atoms, all of which may or may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, or P atoms. This 6-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #9:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms and having at least one additional Nitrogen Atom Binding Site not in a Ring (N Monodentates, N-N Bidentates, N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #10:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Nitrogen Atom Binding Site not in a Ring (N Monodentates, N-N Bidentates, N-N	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to

Tridentates, N-N Tetracentates, or N-N Hexadentates)	the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #11:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Nitrogen Atom Binding Site in a Separate Ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional nitrogen-containing rings that constitute N binding sites. Can include other ring systems bound to the N-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or additional N-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #12:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Nitrogen Atom Binding Site in a Separate Ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates)	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional nitrogen-containing rings that constitute N binding sites. Can include other ring systems bound to the N-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or additional N-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #13:</u> Two-, Three-, Four-, Six-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) and are not contained in Component Heterocyclic Rings (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexadentates)	Macrocyclic ligands containing two, three, four, six, eight, or ten nitrogen binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #14:</u>	Macrocyclic ligands containing a total of four,

Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in Component 5-Membered Heterocyclic Rings (N-N Bidentates, N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	six, eight, or ten five-membered heterocyclic rings containing nitrogen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #15:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in a Combination of 5-Membered Heterocyclic Rings and Amine or Imine Groups (N-N Bidentates, N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide nitrogen binding sites to valence stabilize the central metal ion. Other amine or imine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, six, eight, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #16:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in Component 6-Membered Heterocyclic Rings (N-N Bidentates, N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing a total of four, six, eight, or ten six-membered heterocyclic rings containing nitrogen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #17:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in a Combination of 6-Membered Heterocyclic Rings and Amine or Imine Groups (N-N Bidentates, N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These heterocyclic rings provide nitrogen binding sites to valence stabilize the central metal ion. Other amine or imine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, six, eight, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating

	hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #18:</u> Amidines and Diamidines (N-N Bidentates and N-N Tetracentates)	$R'-NH-C(-R)=N-R''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #19:</u> Biguanides (Imidodicarbonimidic Diamides or Dihydrazides), Biguanidines, Imidotricarbonimidic Diamides or Dihydrazides, Imidotetracarbonimidic Diamides or Dihydrazides, Dibiguanides, Bis(biguanidines), Polybiguanides, and Poly(biguanidines) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$RR'-N-C(=NH)-NR''-C(=NH)-NR'''R''''$ for biguanides, $RR'-N-C(=NH)-NR''-NH-C(=NH)-NR'''R''''$ for biguanidines, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #20:</u> Diamidinomethanes, Bis(amidinomethanes), and Poly(amidinomethanes) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$RR'-N-C(=NH)-CR''R'''-C(=NH)-NR''''R'''''$, where R, R', R'', R''', R'''', and R''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #21:</u> Imidoylguanidines, Amidinoguanidines, Bis(imidoylguanidines), Bis(amidinoguanidines), Poly(imidoylguanidines), and Poly(amidinoguanidines) (N-N Bidentates, N-N Tridentates, N-N Tetracentates)	$RR'-N-C(=NH)-NR''-C(=NH)-R'''$ for imidoylguanidines, and $RR'-N-C(=NH)-NR''-NH-C(=NH)-R'''$ for amidinoguanidines, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #22:</u> Diformamidine oxides (Dicarbonimidic Diamides or Dihydrazides), Tricarbonimidic Diamides or Dihydrazides, Tetracarbonimidic Diamides or Dihydrazides, Bis(diformamidine oxides), and Poly(diformamidine oxides) (N-N Bidentates, N-N Tridentates, N-N	$RR'-N-C(=NH)-O-C(=NH)-NR''R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

Tetradentates)	
<u>N Valence Stabilizer #23:</u> Diформамидине Sulfides (Thiodicarbonimidic Diamides or Dihydrazides), Thiotricarbonimidic Diamides or Dihydrazides, Thiotetracarbonimidic Diamides or Dihydrazides, Bis(diформамидине sulfides), and Poly(diформамидине sulfides) (N-N Bidentates, N-N Tridentates, N-N Tetradentates)	$RR'-N-C(=NH)-S-C(=NH)-NR''R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #24:</u> Imidodicarbonimidic Acids, Diimidodicarbonimidic Acids, Imidotricarbonimidic Acids, Imidotetracarbonimidic Acids, and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)	$R-O-C(=NH)-NR'-C(=NH)-O-R''$ for imidodicarbonimidic acids, and $R-O-C(=NH)-NR'-NH-C(=NH)-O-R''$ for diimidodicarbonimidic acids, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #25:</u> Thioimidodicarbonimidic Acids, Thiodiimidodicarbonimidic Acids, Thioimidotricarbonimidic Acids, Thioimidotetracarbonimidic Acids, and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)	$R-S-C(=NH)-NR'-C(=NH)-S-R''$ for thioimidodicarbonimidic acids, and $R-S-C(=NH)-NR'-NH-C(=NH)-S-R''$ for thiodiimidodicarbonimidic acids, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #26:</u> Diimidoylimines, Diimidoylhydrazides, Bis(diimidoylimines), Bis(diimidoylhydrazides), Poly(diimidoylimines), and Poly(diimidoylhydrazides) (N-N Tridentates and N-N Hexadentates)	$R-C(=NH)-NR'-C(=NH)-R''$ for diimidoylimines, and $R-C(=NH)-NR'-NH-C(=NH)-R''$ for diimidoylhydrazides, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #27:</u> Imidosulfamides, Diimidosulfamides, Bis(imidosulfamides),	$RR'-N-S(=NH)(=O)-OR''$ or $RR'-N-S(=NH)(=O)-N-R''R'''$ for imidosulfamides, and $RR'-N-S(=NH)(=NH)-OR''$ or $RR'-N-$

Bis(diimidosulfamides), Poly(imidosulfamides), and Poly(diimidosulfamides) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$S(=NH)(=NH)-N-R''R'''$ for diimidosulfamides, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #28:</u> Phosphoramidimide Triamides, Bis(phosphoramidimide triamides), and Poly(phosphoramidimide triamides) and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$(NH=P(-NRR')(-NR''R'''))(-NR'''R''''')$, where R, R', R'', R''', R'''', and R''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #29:</u> Phosphoramidimide Acid, Phosphorodiamidimide Acid, Bis(Phosphoramidimide Acid), Bis(Phosphorodiamidimide Acid), Poly(Phosphoramidimide Acid), Poly(Phosphorodiamidimide Acid), and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$(NH=P(-NRR')(OH)_2)$ for phosphoramidimide acid, and $(NH=P(-NRR')(-NR''R'''))(OH)$ for phosphorodiamidimide acid, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #30:</u> Phosphoramidimidodithioic Acid, Phosphorodiamidimidodithioic Acid, Bis(Phosphoramidimidodithioic Acid), Bis(Phosphorodiamidimidodithioic Acid), Poly(Phosphoramidimidodithioic Acid), Poly(Phosphorodiamidimidodithioic Acid), and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates)	$(NH=P(-NRR')(SH)_2)$ for phosphoramidimidodithioic acid, and $(NH=P(-NRR')(-NR''R'''))(SH)$ for phosphorodiamidimidodithioic acid, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #31:</u> Azo compounds including triazenes with amino, imino, oximo, diazeno, or hydrazido substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis[o-(H ₂ N-) or alpha- or beta-(H ₂ N-)azo compounds], or Poly[o-(H ₂ N-) or alpha- or beta-(H ₂ N-)azo compounds) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N	$R-N=N-R'$ for azo compounds, $R-N=N-NH-R'$ for triazenes, where R, and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-amino, imino, oximo, diazeno, or hydrazido substituted aryl azo compounds, and alpha- or beta-amino,

Hexadentates)	imino, oximo, diazeno, or hydrazido alkyl azo compounds.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #32:</u> Diazeneformimidamides (Diazeneamidines), Diazeneacetimidamides (Diazene-alpha-amidinoalkanes(alkenes)), Bis(diazeneformimidamides), Bis(diazeneacetimidamides), Poly(diazeneformimidamides), and Poly(diazeneacetimidamides) (N-N Bidentates, N-N Tetradentates, and N-N Hexadentates)	$R-N=N-C(=NH)-NR'R''$ for diazeneformimidamides, and $R-N=N-CR'R''-C(=NH)-NR'''R''''$ for diazeneacetimidamides, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #33:</u> Diazeneformimidic Acid, Diazeneacetimidic Acid, Bis(diazeneformimidic acid), Bis(diazeneacetimidic acid), Poly(diazeneformimidic acid), Poly(diazeneacetimidic acid), and derivatives thereof (N-N Bidentates, N-N Tetradentates, and N-N Hexadentates)	$R-N=N-C(=NH)-OR'$ for diazeneformimidic acid, and $R-N=N-CR'R''-C(=NH)-OR'''$ for diazeneacetimidic acid, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #34:</u> Diazeneformimidothioic Acid, Diazeneacetimidothioic Acid, Bis(diazeneformimidothioic acid), Bis(diazeneacetimidothioic acid), Poly(diazeneformimidothioic acid), Poly(diazeneacetimidothioic acid), and derivatives thereof (N-N Bidentates, N-N Tetradentates, and N-N Hexadentates)	$R-N=N-C(=NH)-SR'$ for diazeneformimidothioic acid, and $R-N=N-CR'R''-C(=NH)-SR'''$ for diazeneacetimidothioic acid, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #35:</u> Imidoilyldiazenes, Bis(imidoilyldiazenes), and Poly(imidoilyldiazenes), (N-N Bidentates, N-N Tetradentates and N-N Hexadentates)	$R-N=N-C(=NH)-R'$ or $R-N=N-CR'R''-C(=NH)-R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #36:</u> Diazenediformimidamides (1,2- Diazenediamidines),	$RR'-N-C(=NH)-N=N-C(=NH)-NR''R'''$ for diazenediformimidamides, and $RR'-N-C(=NH)-CR''R'''-N=N-CR''''R'''''-C(=NH)-NR''''''R'''''''$

<p>Diazenediacetimidamides (1,2-Diazene-di-alpha-amidinoalkanes(alkenes)), Bis(diazenediformimidamides), Bis(diazenediacetimidamides), Poly(diazenediformimidamides), and Poly(diazenediacetimidamides) (N-N Tridentates and N-N Hexadentates)</p>	<p>for diazenediacetimidamides, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N Valence Stabilizer #37:</u> Diazenediformimidic Acid, Diazenediacetimidic Acid, Bis(diazenediformimidic acid), Bis(diazenediacetimidic acid), Poly(diazenediformimidic acid), and Poly(diazenediacetimidic acid), and derivatives thereof (N-N Tridentates and N-N Hexadentates)</p>	<p>RO-C(=NH)-N=N-C(=NH)-OR' for diazenediformimidic acid, and RO-C(=NH)-CR'R''-N=N-CR'''R''''-C(=NH)-OR'''' for diazenediacetimidic acid, where R, R', R'', R''', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N Valence Stabilizer #38:</u> Diazenediformimidothioic Acid, Diazenediacetimidothioic Acid, Bis(diazenediformimidothioic acid), Bis(diazenediacetimidothioic acid), Poly(diazenediformimidothioic acid), and Poly(diazenediacetimidothioic acid), and derivatives thereof (N-N Tridentates and N-N Hexadentates)</p>	<p>RS-C(=NH)-N=N-C(=NH)-SR' for diazenediformimidothioic acid, and RS-C(=NH)-CR'R''-N=N-CR'''R''''-C(=NH)-SR'''' for diazenediacetimidothioic acid, where R, R', R'', R''', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N Valence Stabilizer #39:</u> Diimidoyldiazenes, Bis(diimidoyldiazenes), and Poly(diimidoyldiazenes), (N-N Tridentates and N-N Hexadentates)</p>	<p>R-C(=NH)-N=N-C(=NH)-R'' or R-C(=NH)-CR'R''-N=N-CR'''R''''-C(=NH)-R''''', where R, R', R'', R''', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N Valence Stabilizer #40:</u> Ortho-amino (or -hydrazido) Substituted Formazans, Bis(o-amino or -hydrazido substituted formazans), and Poly(o-amino or -hydrazido substituted formazans) (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)</p>	<p>R-N=N-CR'=N-NR''R''', where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-amine or hydrazide</p>

	substituted aryl R derivatives, and beta-amine or hydrazide substituted alkyl R derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #41:</u> Ortho-amino (or -hydrazido) Substituted Azines (including ketazines), Bis(o-amino or hydrazido substituted azines), and Poly(o-amino or hydrazido substituted azines) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexadentates)	$RR'C=N-N=CR''R'''$ or $RR'C=N-NR''R'''$ (for ketazines), where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-amine or hydrazide substituted aryl R derivatives, and beta-amine or hydrazide substituted alkyl R derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #42:</u> Schiff Bases with one Imine (C=N) Group and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Bidentates, N-N Tridentates, N-N Tetracentates, N-N Pentadentates, or N-N Hexadentates). Also includes hydrazones with ortho-N substitution.	$RR'C=N-R''$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #43:</u> Schiff Bases with two Imine (C=N) Groups and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution (N-N Bidentates). Also includes dihydrazones.	$RR'C=N-R''-N=CR'''R''''$ or $R-N=C-R'-C=N-R'$ or $RC=N-R'-N=CR''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho-, alpha-, or beta-hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #44:</u> Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Tridentates, N-N Tetracentates, N-N Pentadentates, or N-N Hexadentates). Also includes hydrazones with ortho-N substitution.	$RR'C=N-R''-N=CR'''R''''$ or $R-N=C-R'-C=N-R'$ or $RC=N-R'-N=CR''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution.) Ligand can also contain

	nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #45:</u> Schiff Bases with three Imine (C=N) Groups and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution (N-N Tridentates). Also includes trihydrazones.	$N(-R-N=CR'R'')$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho-, alpha-, or beta-hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #46:</u> Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Tetradentates, N-N Pentadentates, or N-N Hexadentates)	$N(-R-N=CR'R'')$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #1:</u> Macrocyclic, Macrobicyclic, and Macropolycyclic Oligothioketones (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Thioketones (typically in the beta position) (S-S Bidentates, S-S Tetradentates, and S-S Hexadentates)	Macrocyclic ligands containing two, four, or six thioketone binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #2:</u> Macrocyclic, Macrobicyclic, and Macropolycyclic Dithiolenes (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of alpha, alpha dithiols (meaning two thiol groups on a single carbon atom in the ring) (S-S Bidentates, S-S Tetradentates, and S-S Hexadentates)	Macrocyclic ligands containing two, four, six, or eight 1,1-dithiolene binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #3:</u> Dithioimidodialdehydes, Dithiohydrazidodialdehydes (thioacyl thiohydrazides), Bis(dithioimidodialdehydes), Bis(dithiohydrazidodialdehydes),	$RC(=S)-NR'-C(=S)-R''$ for dithioimidodialdehydes, and $RC(=S)-NR'-NH-C(=S)-R''$ for dithiohydrazidodialdehydes (thioacyl thiohydrazides), where R, R', and R'' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms

Poly(dithioimidodialdehydes), and Poly(dithiohydrazidodialdehydes) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #4:</u> Dithioimidodicarbonic acids, Dithiohydrazidodicarbonic acids, Bis(dithioimidodicarbonic acids), Bis(dithiohydrazidodicarbonic acids), Poly(dithioimidodicarbonic acids), Poly(dithiohydrazidodicarbonic acids) and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$R-O-C(=S)-NR'-C(=S)-O-R''$ or $R-S-C(=S)-NR'-C(=S)-S-R''$ for dithioimidodicarbonic acids, and $R-O-C(=S)-NR'-NH-C(=S)-O-R''$ or $R-S-C(=S)-NR'-NH-C(=S)-S-R''$ for dithiohydrazidodicarbonic acids, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #5:</u> 1,3-Dithioketones (Dithio-beta-ketonates), 1,3,5-Trithioketones, Bis(1,3-Dithioketones), and Poly(1,3-Dithioketones) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$R-C(=S)-CR'R''-C(=S)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #6:</u> 1,2-Dithioketones (Dithiolenes, Dithio-alpha-ketonates), 1,2,3-Trithioketones, Dithiotropolonates, ortho-Dithioquinones, Bis(1,2-Dithioketones), and Poly(1,2-Dithioketones) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$R-C(=S)-C(=S)-R'$ where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #7:</u> Dithiomalonamides (Dithiomalonodiamides), Bis(dithiomalonamides), and Polydithiomalonamides (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$RR'-N-C(=S)-CR''R'''-C(=S)-N-R''''R'''''$ where R, R', R'', R''', R''', and R''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #8:</u> 2-Thioacylthioacetamides, Bis(2-thioacylthioacetamides), and Poly(2-thioacylthioacetamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$RR'-N-C(=S)-CR''R'''-C(=S)-R''''$ where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.

	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #9:</u> Dithioacyl sulfides, Bis(dithioacyl sulfides), and Poly(dithioacyl sulfides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$R-C(=S)-S-C(=S)-R'$ where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #10:</u> Trithiodicarbonyl Diamides, Bis(trithiodicarbonyl diamides), and Poly(trithiodicarbonyl diamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$RR'-N-C(=S)-S-C(=S)-N-R''R'''$ where R, R', R'', and R''' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #11:</u> Pentathio-, Tetrathio-, or Trithiodicarbonyl Acids, Bis(pentathio-, tetrathio-, or trithiodicarbonyl acids), Poly(pentathio-, tetrathio-, or trithiodicarbonyl acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$R-S-C(=S)-S-C(=S)-S-R'$ for pentathiodicarbonyl acids, $R-O-C(=S)-S-C(=S)-S-R'$ for tetrathiodicarbonyl acids, and $R-O-C(=S)-S-C(=S)-O-R'$ for pentathiodicarbonyl acids, where R and R' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #12:</u> Dithiohypophosphoric Acids, Bis(dithiohypophosphoric acids), and Poly(dithiohypophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$(R-O)(R'-O)P(=S)-P(=S)(-O-R'')(-O-R''')$; $(R-O)(R'-S)P(=S)-P(=S)(-S-R'')(-O-R''')$; or $(R-S)(R'-S)P(=S)-P(=S)(-S-R'')(-S-R''')$, where R, R', R'', and R''' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to be confused with hypophosphorous acid derivatives (hypophosphites) $(R-O)R''R'''P(=O)$ which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.
<u>S Valence Stabilizer #13:</u> Dithiohypophosphoramides, Bis(dithiohypophosphoramides), and	$(RR'-N)(R''R'''-N)P(=S)-P(=S)(-N-R''''R''''')(-N-R''''''R''''''')$, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH_2 or

Poly(dithiohypophosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to be confused with hypophosphorous acid derivatives (hypophosphites) (R-O-)R''R'''P(=O) which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.
<u>S Valence Stabilizer #14:</u> Dithioimidodiphosphoric Acids, Dithiohydrazidodiphosphoric Acids, Bis(dithioimidodiphosphoric Acids), Bis(dithiohydrazidodiphosphoric Acids), Poly(dithioimidodiphosphoric Acids), Poly(dithiohydrazidodiphosphoric Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(R-O-)(R'-O-)P(=S)-NH-P(=S)(-O-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-NH-P(=S)(-S-R'')(-O-R'''); or (R-S-)(R'-S-)P(=S)-NH-P(=S)(-S-R'')(-S-R''') for dithioimidodiphosphoric acids, and -NH-NH- derivatives for dithiohydrazidodiphosphoric acids, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #15:</u> Dithioimidodiphosphoramides, Dithiohydrazidodiphosphoramides, Bis(dithioimidodiphosphoramides), Bis(dithiohydrazidodiphosphoramides), Poly(dithioimidodiphosphoramides), and Poly(dithiohydrazidodiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(RR'-N-)(R''R'''-N-)P(=S)-NH-P(=S)(-N-R''''R''''')(-N-R''''''R''''''') for dithioimidodiphosphoramides, and (RR'-N-)(R''R'''-N-)P(=S)-NH-NH-P(=S)(-N-R''''R''''')(-N-R''''''R''''''') for dithiohydrazidodiphosphoramides, where R, R', R'', R''', R''''', R''''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #16:</u> Dithiodiphosphoramides, Bis(dithiodiphosphoramides), and Poly(dithiodiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(RR'-N-)(R''R'''-N-)P(=S)-S-P(=S)(-N-R''''R''''')(-N-R''''''R'''''''), or (RR'-N-)(R''R'''-N-)P(=S)-O-P(=S)(-N-R''''R''''')(-N-R''''''R'''''''), where R, R', R'', R''', R''''', R''''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.

	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #17:</u> Dithiodiphosphoric Acids, Bis(dithiophosphoric Acids), Poly(dithiodiphosphoric Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(R-O-)(R'-O-)P(=S)-O-P(=S)(-O-R'')(-O-R'''); (R-O-)(R'-O-)P(=S)-S-P(=S)(-O-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-O-P(=S)(-S-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-S-P(=S)(-S-R'')(-O-R'''); or (R-S-)(R'-S-)P(=S)-S-P(=S)(-S-R'')(-S-R'''), where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #18:</u> Trithiophosphoric Acids (Phosphorotrithioic Acids), Bis(trithiophosphoric acids), Poly(trithiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(O=P(-S-R)(-S-R')(-S-R'')) or (S=P(-S-R)(-S- R')(-O-R'')), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #19:</u> Dithiophosphoric Acids (Phosphorodithioic Acids), Bis(dithiophosphoric acids), Poly(dithiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(O=P(-S-R)(-S-R')(-O-R'')) or (S=P(-S-R)(-O- R')(-O-R'')), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #20:</u> Tetrathiophosphoric Acids (Phosphorotetrathioic Acids), Bis(tetrathiophosphoric acids), Poly(tetrathiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(S=P(-S-R)(-S-R')(-S-R'')), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #21:</u> Phosphoro(dithioperoxo)dithioic Acids, Bis[phosphoro(dithioperoxo)dithioic Acids], Poly[phosphoro(dithioperoxo)dithioic Acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S	(O=P(-S-S-R)(-S-R')(-S-R'')) or (S=P(-S-S- R)(-S-R')(-O-R'')), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached.

Tetradentates)	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #22:</u> Phosphoro(dithioperoxo)thioic Acids, Bis[phosphoro(dithioperoxo)thioic Acids], Poly[phosphoro(dithioperoxo)thioic Acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$(O=P(-S-S-R)(-S-R')(-O-R''))$ or $(S=P(-S-S-R)(-O-R')(-O-R''))$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #23:</u> Phosphoro(dithioperoxo)trithioic Acids, Bis[phosphoro(dithioperoxo)trithioic Acids], Poly[phosphoro(dithioperoxo)trithioic Acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$(S=P(-S-S-R)(-S-R')(-S-R''))$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #24:</u> Beta-Mercapthothioketones, Beta-Mercapthothioaldehydes, Bis(beta-mercapthothioketones), Bis(beta-mercapthothioaldehydes), Poly(beta-mercapthothioketones), and Poly(beta-mercapthothioaldehydes) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$R-CR'(-SH)-CH_2-C(=S)-R''$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #25:</u> N-(Aminomethylthiol)thioureas [N-(Aminomercaptomethyl)thioureas], Bis[N-(aminomethylthiol)thioureas], and Poly[N-(aminomethylthiol)thioureas] (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$RR'-N-CH(-SH)-NR''-C(=S)-NR'''R''''$, where R, R', R'', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #26:</u> Dithiooxamides, Bis(dithiooxamides), and Poly(dithiooxamides) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$RR'-N-C(=S)-C(=S)-N-R''R'''$, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #27:</u> 1,1-Dithiolates, Bis(1,1-dithiolates), and Poly(1,1-dithiolates) (S-S Bidentates and S-	$RR'-C=C(S^-)(S^-)$, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to

S Tetradentates)	40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #28:</u> Dithiomonocarboxylic Acids, Tri- and Tetrathiodicarboxylic Acids, Bis(dithiomonocarboxylic Acids), Bis(tri- and tetrathiodicarboxylic acids), Poly(dithiomonocarboxylic acids), Poly(tri- and tetrathiodicarboxylic acids), and derivatives thereof (S-S Bidentates and S-S Tetradentates)	$R-C(=S)(-S-R')$ for dithiomonocarboxylic acids, and $(R-S-)(S=)C-R'-C(=S)(-S-R'')$ for tri- and tetrathiodicarboxylic acids, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #29:</u> Perthiomonocarboxylic Acids, Perthiodicarboxylic Acids, Bis(perthiomonocarboxylic acids), Bis(perthiodicarboxylic acids), Poly(perthiomonocarboxylic acids), Poly(perthiodicarboxylic acids), and derivatives thereof (S-S Bidentates and S-S Tetradentates)	$R-C(=S)(-S-S-R')$ for perthiomonocarboxylic acids, and $(R-S-S-)(S=)C-R'-C(=S)(-S-S-R'')$ for perthiodicarboxylic acids, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #30:</u> Dithiocarbonates, Trithiocarbonates, Perthiocarbonates, Bis(dithiocarbonates), Bis(trithiocarbonates), and Bis(perthiocarbonates) (S-S Bidentates and S-S Tetradentates)	$R-S-C(=S)-O-R'$ or $R-S-C(=O)-S-R'$ for dithiocarbonates, $R-S-C(=S)-S-R'$ for trithiocarbonates, and $R-S-S-C(=S)-S-R'$ for perthiocarbonates, where R, and R' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #31:</u> Dithiocarbamates, Bis(dithiocarbamates), and Poly(dithiocarbamates) (including N-hydroxydithiocarbamates and N-mercaptodithiocarbamates) (S-S Bidentates, S-S Tridentates, and S-S Tetradentates)	$RR'N^+=C(SH)(SH)$, where R and R' represent H, OH, SH, OR'' (R'' = C_1-C_{30} alkyl or aryl), SR'' (R'' = C_1-C_{30} alkyl or aryl), NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #32:</u> Dithiocarbazates (Dithiocarbazides), Bis(dithiocarbazates), and	$RR'N-NR''-C(=S)(SH)$, where R and R' represent H, NH_2 or any organic functional group wherein the number of carbon atoms

Poly(dithiocarbazates) (S-S Bidentates, S-S Tridentates, and S-S Tetracentates; or possibly N-S Bidentates, N-S Tridentates, and N-S Tetracentates)	ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #33:</u> Thiocyanate ligands (S Monodentates)	Thiocyanates bound directly to the high valence metal ion.
<u>O Valence Stabilizer #1:</u> Biurets (Imidodicarbonic Diamides), Isobiurets, Biureas, Triurets, Triureas, Bis(biurets), Bis(isobiurets), Bis(biureas), Poly(biurets), Poly(isobiurets), and Poly(biureas) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$RR'-N-C(=O)-NR''-C(=O)-NR'''R''''$ for biurets, and $RR'-N-C(=O)-NR''-NH-C(=O)-NR'''R''''$ for biureas, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #2:</u> Acylureas, Aroylureas, Bis(acylureas), Bis(aroylureas), Poly(acylureas), and Poly(aroylureas) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$RR'-N-C(=O)-NR''-C(=O)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #3:</u> Imidodialdehydes, Hydrazidodialdehydes (Acyl hydrazides), Bis(imidodialdehydes), Bis(hydrazidodialdehydes), Poly(imidodialdehydes), and Poly(hydrazidodialdehydes) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$RC(=O)-NR'-C(=O)-R''$ for imidodialdehydes, and $RC(=O)-NR'-NH-C(=O)-R''$ for hydrazidodialdehydes (acyl hydrazides), where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #4:</u> Imidodicarbonic acids, Hydrazidodicarbonic acids, Bis(imidodicarbonic acids), Bis(hydrazidodicarbonic acids), Poly(imidodicarbonic acids), Poly(hydrazidodicarbonic acids) and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$R-O-C(=O)-NR'-C(=O)-O-R''$ for imidodicarbonic acids, and $R-O-C(=O)-NR'-NH-C(=O)-O-R''$ for hydrazidodicarbonic acids, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #5:</u>	$RR'-N-S(=O)(=O)-NR''-S(=O)(=O)-NR'''R''''$

Imidodisulfamic Acid, Imidodisulfuric Acid, Bis(Imidodisulfamic Acid), Bis(Imidodisulfuric Acid), Poly(Imidodisulfamic Acid), and Poly(Imidodisulfuric Acid) and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	for imidodisulfamic acid, and $R-O-S(=O)(=O)-NR'-S(=O)(=O)-OR''$ for imidosulfuric acid, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #6:</u> 1,3-Diketones (Beta-Diketonates), 1,3,5-Triketones, Bis(1,3-Diketones), and Poly(1,3-Diketones), all with a Molecular Weight Greater than 125 (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$R-C(=O)-CR'R''-C(=O)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. If these ligands exhibit a molecular weight less than or equal to 125, the solubility of the resultant diketonate complex will be too high.
<u>O Valence Stabilizer #7:</u> 1,2-Diketones (Alpha-Diketonates), 1,2,3-Triketones, Tropolonates, ortho-Quinones, Bis(1,2-Diketones), and Poly(1,2-Diketones), all with a Molecular Weight Greater than 100 (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$R-C(=O)-C(=O)-R'$ where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. If these ligands exhibit a molecular weight less than or equal to 100, the solubility of the resultant diketonate complex will be too high.
<u>O Valence Stabilizer #8:</u> Malonamides (Malonodiamides), Bis(malonamides), and Polymalonamides (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$RR'-N-C(=O)-CR'R''-C(=O)-N-R'''R''''$ where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #9:</u> 2-Acylacetamides, Bis(2-acylacetamides), and Poly(2-acylacetamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$RR'-N-C(=O)-CR'R''-C(=O)-R'''$ where R, R', R'', R''', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

<p><u>O Valence Stabilizer #10:</u> Monothiodicarbonic Diamides, Bis(monothiodicarbonic diamides), and Poly(monothiodicarbonic diamides) (O-O Bidentates, O-O Tridentates, O-O Tetradentates)</p>	<p>$RR'-N-C(=O)-S-C(=O)-N-R''R'''$ where R, R', R'', and R''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>O Valence Stabilizer #11:</u> Monothiodicarbonic Acids, Bis(monothiodicarbonic acids), Poly(monothiodicarbonic acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetradentates)</p>	<p>$R-O-C(=O)-S-C(=O)-O-R'$, where R and R' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>O Valence Stabilizer #12:</u> Trithionic acid, Bis(trithionic acid), Poly(trithionic acid), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetradentates)</p>	<p>$R-O-S(=O)(=O)-S-S(=O)(=O)-O-R'$, where R and R' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>O Valence Stabilizer #13:</u> Hypophosphoric Acids, Bis(hypophosphoric acids), and Poly(hypophosphoric acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetradentates)</p>	<p>$(R-O)(R'-O)P(=O)-P(=O)(-O-R'')(-O-R''')$, where R, R', R'', and R''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to be confused with hypophosphorous acid derivatives (hypophosphites) $(R-O)R''R'''P(=O)$ which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.</p>
<p><u>O Valence Stabilizer #14:</u> Hypophosphoramides, Bis(hypophosphoramides), and Poly(hypophosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetradentates)</p>	<p>$(RR'-N)(R''R'''-N)P(=O)-P(=O)(-N-R''''R''''')(-N-R''''''R''''''')$, where R, R', R'', R''', R''', R''''', R''''', and R'''''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to</p>

	be confused with hypophosphorous acid derivatives (hypophosphites) $(R-O-R''R''')P(=O)$ which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.
O Valence Stabilizer #15: Imidodiphosphoric Acids, Hydrazidodiphosphoric Acids, Bis(imidodiphosphoric Acids), Bis(hydrazidodiphosphoric Acids), Poly(imidodiphosphoric Acids), Poly(hydrazidodiphosphoric Acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(R-O-)(R'-O-)P(=O)-NH-P(=O)(-O-R'')(-O-R''')$ for imidodiphosphoric acids, and $(R-O-)(R'-O-)P(=O)-NH-NH-P(=O)(-O-R'')(-O-R''')$ for hydrazidodiphosphoric acids; where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
O Valence Stabilizer #16: Imidodiphosphoramides, Hydrazidodiphosphoramides, Bis(imidodiphosphoramides), Bis(hydrazidodiphosphoramides), Poly(imidodiphosphoramides), and Poly(hydrazidodiphosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(RR'-N-)(R''R'''-N-)P(=O)-NH-P(=O)(-N-R''''R''''')(-N-R''''''R''''''')$ for imidodiphosphoramides, and $-NH-NH-$ derivatives for hydrazidodiphosphoramides, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
O Valence Stabilizer #17: Diphosphoramides, Bis(diphosphoramides), and Poly(diphosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(RR'-N-)(R''R'''-N-)P(=O)-O-P(=O)(-N-R''''R''''')(-N-R''''''R''''''')$, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
O Valence Stabilizer #18: Beta-Hydroxyketones, Beta-Hydroxyaldehydes, Bis(beta-hydroxyketones), Bis(beta-hydroxyaldehydes), Poly(beta-hydroxyketones), and Poly(beta-hydroxyaldehydes) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$R-CR'(-OH)-CH_2-C(=O)-R''$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
O Valence Stabilizer #19:	$RR'-N-C(=O)-C(=O)-N-R''R'''$, where R, R',

Oxamides, Bis(oxamides), and Poly(oxamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #20:</u> Squaric Acids and derivatives thereof (O-O Bidentates)	-C(-OH)=C(-OH)-, where the two carbon atoms supporting the hydroxy groups are included within a cyclic hydrocarbon moiety, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #21:</u> Dicarboxylic Acids, Bis(dicarboxylic acids), Poly(dicarboxylic acids), and derivatives thereof (O-O Bidentates and O-O Tetracentates)	(R-O-)(O=)C-R'-C(=O)(-O-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #22:</u> Carbonates and Bis(carbonates) (O-O Bidentates and O-O Tetracentates)	R-O-C(=O)-O-R', where R, and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #23:</u> Carbamates, Bis(carbamates), and Poly(carbamates) (including N-hydroxycarbamates and N-mercaptopcarbamates) (O-O Bidentates, O-O Tridentates, and O-O Tetracentates)	RR'N ⁺ =C(OH)(OH), where R and R' represent H, OH, SH, OR'' (R'' = C ₁ -C ₃₀ alkyl or aryl), SR'' (R'' = C ₁ -C ₃₀ alkyl or aryl), NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #24:</u> Carbimides, Bis(carbimides), and Poly(carbimides) (O-O Bidentates, O-O Tridentates, and O-O Tetracentates)	RN=C(OH)(OH), where R represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #25:</u>	RR'-N-CH(-OH)-NR''-C(=O)-NR'''R''', where

N-(Aminomethylol)ureas [N-(Aminohydroxymethyl)ureas], Bis[N-(aminomethylol)ureas], and Poly[N-(aminomethylol)ureas] (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	R, R', R'', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #26:</u> Cyanate ligands (O Monodentates)	Cyanates bound directly to the high valence metal ion.
<u>N-S Valence Stabilizer #1:</u> Diформамидине Disulfides (Thioperoxydicarbonimidic Diamides or Dihydrazides), Thioperoxytricarbonimidic Diamides or Dihydrazides, Thioperoxytetracarbonimidic Diamides or Dihydrazides, Bis(diформамидине disulfides), and Poly(diформамидине disulfides) (N-S Bidentates, N-S Tridentates, N-S Tetracentates)	RR'-N-C(=NH)-S-S-C(=NH)-NR''R''', where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #2:</u> S-Amidinodithiocarbamates, Bis(S-amidinodithiocarbamates), and Poly(S-amidinodithiocarbamates) (N-S Bidentates and N-S Tetracentates)	RR'-N-C(=NH)-S-CS-NR''R''', where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #3:</u> O-Amidinothiocarbamates, Bis(O-amidinothiocarbamates), and Poly(O-amidinothiocarbamates) (N-S Bidentates and N-S Tetracentates)	RR'-N-C(=NH)-O-CS-NR''R''', where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #4:</u> S-Amidinoperoxythiocarbamates, Bis(S-amidinoperoxythiocarbamates), and Poly(S-amidinoperoxythiocarbamates) (N-S Bidentates and N-S Tetracentates)	RR'-N-C(=NH)-S-S-CS-NR''R''', where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #5:</u> Phosphorimidodithioic Acid; Phosphorimidodithioic Acid;	(NH=)P(-SR)(-OR')(-OR'') for phosphorimidodithioic acid, (NH=)P(-SR)(-SR')(-OR'') for phosphorimidodithioic acid, (NH=)P(-

Phosphorimidotrithioic Acid; Bis(Phosphorimidothioic Acid); Bis(Phosphorimidodithioic Acid); Bis(Phosphorimidotrithioic Acid); Poly(Phosphorimidothioic Acid); Poly(Phosphorimidodithioic Acid); Poly(Phosphorimidotrithioic Acid); and derivatives thereof (N-S Bidentates and N-S Tetradentates)	SR)(-SR')(-SR'') for phosphorimidotrithioic acid, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #6:</u> Phosphorothioic Triamides, Bis(phosphorothioic triamides), and Poly(phosphorothioic triamides) (N-S Bidentates and N-S Tetradentates)	(S=)P(-NRR')(-NR''R''')(-NR''''R'''''), where R, R', R'', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #7:</u> Phosphoramidotrithioic Acid, Phosphorodiamidodithioic Acid, Bis(phosphoramidotrithioic acid), Bis(phosphorodiamidodithioic acid), poly(phosphoramidotrithioic acid), poly(phosphorodiamidodithioic acid), and derivatives thereof (N-S Bidentates and N-S Tetradentates)	(S=)P(-NRR')(-SR'')(-SR''') for phosphoramidotrithioic acid, and (S=)P(-NRR')(-NR''R''')(-SR''') for phosphorodiamidodithioic acid, where R, R', R'', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #8:</u> Phosphoramidothioic Acid, Phosphoramidodithioic Acid, Phosphorodiamidothioic Acid, Bis(Phosphoramidothioic Acid), Bis(Phosphoramidodithioic Acid), Bis(Phosphorodiamidothioic Acid), Poly(Phosphoramidothioic Acid), Poly(Phosphoramidodithioic Acid), and Poly(Phosphorodiamidothioic Acid) (N-S Bidentates and N-S Tetradentates)	(O=)P(-NRR')(-SR'')(-OR''') or (S=)P(-NRR')(-OR'')(-OR''') for phosphoramidothioic acid; (O=)P(-NRR')(-SR'')(-SR''') or (S=)P(-NRR')(-SR'')(-OR''') for phosphoramidodithioic acid; . (O=)P(-NRR')(-NR''R''')(-SR''') or (S=)P(-NRR')(-NR''R''')(-OR''') for phosphorodiamidothioic acid, where R, R', R'', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #9:</u> N-Thioacyl 7-Aminobenzylidenimines (N-S Bidentates or N-S Tetradentates)	R'-C(=S)-N=C(-R)(-NHR''), where R is an aromatic derivative (i.e., -C ₆ H ₅), and R' and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms

	ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #10:</u> Thiohydroxamates (Thiohydroxylamines), Bis(thiohydroxamates), and Poly(thiohydroxamates) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates)	$R-C(=S)-NR'-OH$ or $R-C(-SH)=N-OH$, where R and R' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #11:</u> Alpha- or ortho-Aminothiocarboxylic Acids, and alpha- or ortho-Aminothiodicarboxylic Acids, and derivatives thereof (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	$R-CH(-NHR')-C(=S)(-OH)$ or $R-CH(-NHR')-C(=S)(-SH)$ for aminothiocarboxylic acids, and $(HO-)(S=)C-CH(-NHR)-R'-CH(-NHR'')$ or $(HS-)(S=)C-CH(-NHR)-R'-CH(-NHR'')$ for aminothiodicarboxylic acids, where R, R', and R'' represent any organic functional group wherein the number of carbon atoms ranges from 1 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #12:</u> Thiosemicarbazones, Bis(thiosemicarbazones), and Poly(thiosemicarbazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates)	$RR'-N-C(=S)-NR''-N=CR'''R''''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #13:</u> Thioacyl hydrazones, Bis(thioacyl hydrazones), and Poly(thioacyl hydrazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates)	$R-C(=S)-NR'-N=CR'''R''''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #14:</u> Thiocarbazones (Diazenecarbothioic hydrazides), Bis(thiocarbazones), and Poly(thiocarbazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates)	$R-N=N-C(=S)-NR'-NR''R'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-

	insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #15:</u> Azo compounds including triazenes with thiol or mercapto or thiocarbonyl substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis[o-(HS-) or alpha- or beta-(HS-)azo compounds], or Poly[o-(HS-) or alpha- or beta-(HS-)azo compounds] (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexadentates)	$R-N=N-R'$ for azo compounds, $R-N=N-NH-R'$ for triazenes, where R, and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-thio, mercapto, or thiocarbonyl substituted aryl azo compounds, and alpha- or beta-thio, mercapto, or thiocarbonyl alkyl azo compounds.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #16:</u> Diazeneformothioamides, Diazeneacetothioamides, Bis(diazeneformothioamides), Bis(diazeneacetothioamides), Poly(diazeneformothioamides), and Poly(diazeneacetothioamides) (N-S Bidentates, N-S Tetracentates, and N-S Hexadentates)	$R-N=N-C(=S)-NR'R''$ for diazeneformothioamides, and $R-N=N-CR'R''-C(=S)-NR'''R''''$ for diazeneacetothioamides, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #17:</u> Diazenecarbothioic acids, Diazenecarbodithioic acids, Bis(diazenecarbothioic acids), Bis(diazenecarbodithioic acids), Poly(diazenecarbothioic acids), Poly(diazenecarbodithioic acids) and derivatives thereof (N-S Bidentates, N-S Tetracentates, N-S Hexadentates)	$R-N=N-C(=S)-O-R'$ or $R-N=N-CR'R''-C(=S)-O-R'''$ for diazenecarbothioic acids, and $R-N=N-C(=S)-S-R'$ or $R-N=N-CR'R''-C(=S)-S-R'''$ for diazenecarbodithioic acids, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #18:</u> Diazeneformothioaldehydes, Diazeneacetothioaldehydes, Bis(diazeneformothioaldehydes), Bis(diazeneacetothioaldehydes), Poly(diazeneformothioaldehydes), and Poly(diazeneacetothioaldehydes) (N-S Bidentates, N-S Tetracentates and N-S Hexadentates)	$R-N=N-C(=S)-R'$ for diazeneformothioaldehydes, and $R-N=N-CR'R''-C(=S)-R'''$ for diazeneacetothioaldehydes, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or

	P atoms.
<u>N-S Valence Stabilizer #19:</u> Diazenediformothioamides, Diazenediacetothioamides, Bis(diazenediformothioamides), Bis(diazenediacetothioamides), Poly(diazenediformothioamides), and Poly(diazenediacetothioamides) (N-S Tridentates and N-S Hexadentates)	$RR'-N-C(=S)-N=N-C(=S)-NR''R'''$ or $RR'-N-C(=S)-N=N-C(=O)-NR''R'''$ for diazenediformothioamides, and $RR'-N-C(=S)-CR''R'''-N=N-CR''''R''''-C(=S)-NR''''''R''''''$ or $RR'-N-C(=S)-CR''R'''-N=N-CR''''R''''-C(=O)-NR''''''R''''''$ for diazenediacetothioamides, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #20:</u> Diazenedicarbothioic acids, Diazenedicarbodithioic acids, Bis(diazenedicarbothioic acids), Bis(diazenedicarbodithioic acids), Poly(diazenedicarbothioic acids), Poly(diazenedicarbodithioic acids) and derivatives thereof (N-S Tridentates and N-S Hexadentates)	$R-O-C(=S)-N=N-C(=S)-O-R'$, $R-O-C(=S)-CR''R'''-N=N-CR''''R''''-C(=S)-O-R''''$, $R-O-C(=S)-N=N-C(=O)-O-R'$, or $R-O-C(=S)-CR''R'''-N=N-CR''''R''''-C(=O)-O-R''''$ for diazenedicarbothioic acids, and $R-S-C(=S)-N=N-C(=S)-S-R'$ or $R-S-C(=S)-CR''R'''-N=N-CR''''R''''-C(=S)-S-R''''$ for diazenedicarbodithioic acids, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #21:</u> Diazenediformothioaldehydes, Diazenediacetothioaldehydes, Bis(diazenediformothioaldehydes), Bis(diazenediacetothioaldehydes), Poly(diazenediformothioaldehydes), and Poly(diazenediacetothioaldehydes) (N-S Tridentates and N-S Hexadentates)	$RC(=S)-N=N-C(=S)-R'$ or $RC(=S)-N=N-C(=O)-R'$ for diazenediformothioaldehydes, and $RC(=S)-CR''R'''-N=N-CR''''R''''-C(=S)-R''''$ or $RC(=S)-CR''R'''-N=N-CR''''R''''-C(=O)-R''''$ for diazenediacetothioaldehydes, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #22:</u> Ortho-thio (or -mercapto) Substituted Formazans, Bis(o-thio or -mercapto substituted formazans), and Poly(o-thio or -	$R-N=N-CR'=N-NR''R'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen

mercapto substituted formazans) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-thio or mercapto substituted aryl R derivatives, and beta-thio or mercapto substituted alkyl R derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #23:</u> Ortho-thio (or -mercapto) Substituted Azines (including ketazines), Bis(o-thio or mercapto substituted azines), and Poly(o-thio or mercapto substituted azines) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	$RR'C=N-N=CR''R'''$ or $RR'C=N-NR''R'''$ (for ketazines), where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-thio or mercapto substituted aryl R derivatives, and beta-thio or mercapto substituted alkyl R derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #24:</u> Schiff Bases with one Imine (C=N) Group and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Bidentates, N-S Tridentates, N-S Tetradentates, N-S Pentadentates, or N-S Hexadentates). Also includes Schiff Bases derived from the reaction of carbonyl compounds with dithiocarbazates, and hydrazones with ortho-S substitution.	$RR'C=N-R''$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #25:</u> Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Tridentates, N-S Tetradentates, N-S Pentadentates, or N-S Hexadentates). Also includes Schiff Bases derived from the reaction of carbonyl compounds with dithiocarbazates, and hydrazones with ortho-S substitution.	$RR'C=N-R''-N=CR'''R''''$ or $R-N=C-R'-C=N-R'$ or $RC=N-R'-N=CR''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #26:</u> Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Tetradentates, N-S Pentadentates, or N-S Hexadentates). Also includes Schiff Bases derived from the	$N(-R-N=CR'R'')_3$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-thio or mercapto or thiocarbonyl

reaction of carbonyl compounds with dithiocarbazates, and hydrazones with ortho-S substitution.	substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #27:</u> Thioalkyl Amines (Aminothiols or Aminodisulfides) and Thioalkyl Imines (Iminothiols or Iminodisulfides) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	$[R-CR'(-NR''R''')]_x-R''''-[C(-SR''''')R''''''R''''''']_y$, $[R-CR'(-NR''R''')]_x-R''''-[C(-S-S-R''''')R''''''R''''''']_y$, or $[R-CR'(-NR''R''')]_x-R''''-[C(=S)R''''']_y$ for thioalkyl amines; and $[R-C(=NR')]_x-R''-[C(-SR''')R''''R''''']_y$, $[R-C(=NR')]_x-R''-[C(-S-SR''')R''''R''''']_y$, or $[R-C(=NR')]_x-R''-[C(=S)R''']_y$ for thioalkyl imines, where R, R', R'', R''', R''', R''', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x and y = 1-6. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #28:</u> Thioaryl Amines and Thioaryl Imines (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	$[R(-NR'R'')(-SR'')]$, $[R(-NR'R'')(-S-S-R'')]$, $[R(-NR'R'')(-C(=S)R'')]$, $[R(-NR'R'')_x]_2S$, $[R(-NR'R'')_x]_{2-3}R'''(-SR''')_y$, $[R(-SR')_x]_{2-3}R'''(-NR''R''')_y$, $[R(-NR'R'')_x]_2S_2$, and $[R(-NR'R'')_x]_2R'''(C(=S))_yR''''$ for thioaryl amines; and $[R(-SR')_x]_2NH$ or $[R(-SR')_x]_2NHNH$ for thioaryl imines, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x = 0-2 and y = 1-4. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #29:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Sulfur Atom Binding Site not in a Ring (N-S Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional sulfur-containing substituents (usually thiols, mercaptans, disulfides, or thiocarbonyls) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-

	insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #30:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Sulfur Atom Binding Site not in a Ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexadentates)	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional sulfur-containing substituents (usually thiols, mercaptans, disulfides, or thiocarbonyls) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #31:</u> Five-Membered Heterocyclic Rings containing One or Two Sulfur Atoms at least one additional Nitrogen Atom Binding Site not in a Ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexadentates)	Five membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines, imines, or hydrazides) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #32:</u> Six-Membered Heterocyclic Rings containing One or Two Sulfur Atoms at least one additional Nitrogen Atom Binding Site not in a Ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexadentates)	Six membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines, imines, or hydrazides) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #33:</u> Five-Membered Heterocyclic Rings	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In

containing One, Two, Three, or Four Nitrogen Atoms at least one additional Sulfur Atom Binding Site in a Separate Ring (N-S Bidentates, N-S Tridentates, N-S Tetradentates)	addition, ligand contains additional sulfur-containing rings that constitute S binding sites. Can include other ring systems bound to the N- or S-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or additional S-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #34:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms at least one additional Sulfur Atom Binding Site in a Separate Ring (N-S Bidentates, N-S Tridentates, N-S Tetradentates)	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional sulfur-containing rings that constitute S binding sites. Can include other ring systems bound to the N- or S-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or additional S-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #35:</u> Two-, Three-, Four-, Six-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) or Sulfur (usually thiols, mercaptans, or thiocarbonyls) and are not contained in Component Heterocyclic Rings (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	Macrocyclic ligands containing two, three, four, six, eight, or ten binding sites composed of nitrogen and sulfur to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #36:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Sulfur and are contained in Component Heterocyclic Rings (N-S Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates)	Macrocyclic ligands containing a total of four, six, eight, or ten heterocyclic rings containing nitrogen or sulfur binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.

<p><u>N-S Valence Stabilizer #37:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Sulfur and are contained in a Combination of Heterocyclic Rings and Amine, Imine, Thiol, Mercapto, or Thiocarbonyl Groups (N-S Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates)</p>	<p>Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide nitrogen or sulfur binding sites to valence stabilize the central metal ion. Other amine, imine, thiol, mercapto, or thiocarbonyl binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, six, eight, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.</p>
<p><u>N-O Valence Stabilizer #1:</u> N-Hydroxy(or N,N'-dihydroxy)amidines and N-Hydroxy(or N,N'-dihydroxy)diamidines (N-O Bidentates, N-O Tridentates, or N-O Tetradentates)</p>	<p>$R'-N(-OH)-C(-R)=N-R''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #2:</u> Guanylureas, Guanidinoureas, Bis(guanylureas), Bis(guanidinoureas), Poly(guanylureas), and Poly(guanidinoureas) (N-O Bidentates and N-O Tetradentates)</p>	<p>$RR'-N-C(=NH)-NR''-CO-NR'''R''''$ for guanylureas, and $RR'-N-C(=NH)-NR''-NH-CO-NR'''R''''$ for guanidinoureas, where R, R', R'', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #3:</u> Amidinoamides, Guanidinoamides, Bis(amidinoamides), Bis(guanidinoamides), Poly(amidinoamides), and Poly(guanidinoamides) (including both N-amidinoamides and 2-amidinoacetamides) (N-O Bidentates and N-O Tetradentates)</p>	<p>$RR'-N-C(=NH)-NR''-CO-R'''$ for N-amidinoamides, or $RR'-N-C(=NH)-CR''R'''-CO-N-R''''R'''''$ for 2-amidinoacetamides, and $RR'-N-C(=NH)-NR''-NH-CO-R'''$ for guanidinoamides, where R, R', R'', R''', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #4:</u> Imidoamides, Bis(imidoamides), and</p>	<p>$R-C(=NH)-NR'-CO-R''$, where R, R', and R'', represent H or any organic functional group</p>

Poly(imidoylamides) (N-O Bidentates and N-O Tetracentates)	wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #5:</u> O-Amidinocarbamates, Bis(O-amidinocarbamates), and Poly(O-amidinocarbamates) (N-O Bidentates and N-O Tetracentates)	$RR'-N-C(=NH)-O-CO-NR''R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #6:</u> S-Amidinothiocarbamates, Bis(S-amidinothiocarbamates), and Poly(S-amidinothiocarbamates) (N-O Bidentates and N-O Tetracentates)	$RR'-N-C(=NH)-S-CO-NR''R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #7:</u> Diimidosulfuric Acid, Bis(diimidosulfuric acid), and derivatives thereof (N-O Bidentates and N-O Tetracentates)	$(NH=)(NH=)P(OR)(OR')$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #8:</u> Phosphorimidic Acid, Bis(phosphorimidic acid); and Poly(phosphorimidic acid), and derivatives thereof (N-O Bidentates)	$(NH=)P(-OR)(-OR')(-OR'')$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #9:</u> Phosphoric Triamides, Bis(phosphoric triamides), and Poly(phosphoric triamides) (N-O Bidentates and N-O Tetracentates)	$(O=)P(-NRR')(-NR''R''')(-NR''''R''''')$, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #10:</u>	$(O=)P(-NRR')(-OR'')(-OR''')$ for

Phosphoramidic Acid, Phosphorodiamidic Acid, Bis(phosphoramidic acid), Bis(phosphorodiamidic acid), Poly(phosphoramidic acid), Poly(phosphorodiamidic acid), and derivatives thereof (N-O Bidentates and N-O Tetradentates)	phosphoramidic acid and $(O=P(-NRR')(-NR''R'''))(-OR''')$ for phosphorodiamidic acid, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #11:</u> N-Acyl 7-Aminobenzylidenimines (N-O Bidentates or N-O Tetradentates)	$R'-C(=O)-N=C(-R)(-NHR'')$, where R is an aromatic derivative (i.e., -C ₆ H ₅), and R' and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or waterinsolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #12:</u> Oximes, Dioximes, and Poly(oximes) (N-O Bidentates, N-O Tridentates, and N-O Tetradentates)	$R-C(=NOH)-R'$ for oximes, and $R-C(=NOH)-C(=NOH)-R'$ for dioximes, where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #13:</u> Carbonyl oximes, Bis(carbonyl oximes), and Poly(carbonyl oximes) (N-O Bidentates, N-O Tridentates, and N-O Tetradentates)	$R-C(=O)-C(=NOH)-R'$, where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #14:</u> Imine oximes, Bis(imine oximes), and Poly(imine oximes) (including 2-nitrogen heterocyclic oximes) (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	$R-C(=N-R'')-C(=NOH)-R'$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #15:</u> Hydroxy oximes, Bis(hydroxy oximes), and Poly(hydroxy oximes) (including 2-oxygen heterocyclic oximes) (N-O Bidentates, N-O	$R-CH(-OH)-C(=NOH)-R'$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen

Tridentates, N-O Tetradentates, and N-O Hexadentates)	or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #16:</u> Amino oximes, Bis(amino oximes), and Poly(amino oximes) (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	$RR'-C(-NH-R'')-C(=NOH)-R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #17:</u> Amido oximes, Bis(amido oximes), and Poly(amido oximes) (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	$RR'-N-C(=NOH)-R''$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #18:</u> Azo oximes, Bis(azo oximes), and Poly(azo oximes) (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates). Also includes hydrazone oximes.	$R-N=N-C(=NOH)-R'$ or $RR'C=N-NR''-C(=NOH)-R'''$, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (R is typically an aryl group.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #19:</u> 2-Nitrosophenols (o-Quinone monoximes) (N-O Bidentates)	$o-(ON-)(HO-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #20:</u> 2-Nitrophenols (N-O Bidentates)	$o-(O_2N-)(HO-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #21:</u> Hydroxamates (Hydroxylamines), Bis(hydroxamates), and	$R-C(=O)-NR'-OH$ or $R-C(-OH)=N-OH$, where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon

Poly(hydroxamates) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)	atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #22:</u> N-Nitrosohydroxylamines, Bis(N-nitrosohydroxylamines), and Poly(N-nitrosohydroxylamines) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)	$R-N(-NO)-OH$, where R represents any organic functional group wherein the number of carbon atoms ranges from 1 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (R is typically an aryl or heterocyclic group.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #23:</u> Amino Acids and ortho-Aminocarboxylic Acids, Peptides, Polypeptides, and Proteins [N-O Bidentates, N-O Tridentates, and N-O Tetradentates; possibly S-O dentates for sulfur-contg. examples such as penicillamine and cystine]	$R-CH(-NHR')-C(=O)(-OH)$ for amino acids and ortho-aminocarboxylic acids, and $R-CH(-NHR')-C(=O)-(NR'')CH(-R''')-C(=O)(-OH)$ for peptides, where R, R', R'', and R''' represent any organic functional group wherein the number of carbon atoms ranges from 1 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #24:</u> Amides, Bis(amides), and Poly(amides), including lactams (N-O Bidentates, N-O Tridentates, and N-O Tetradentates)	$RCONR'R''$, where R, R', and R'' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #25:</u> Semicarbazones, Bis(semicarbazones), and Poly(semicarbazones) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)	$RR'-N-C(=O)-NR''-N=CR'''R''''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #26:</u> Acyl hydrazones, Bis(acyl hydrazones), and Poly(acyl hydrazones) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)	$R-C(=O)-NR'-N=CR''R'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

<p><u>N-O Valence Stabilizer #27:</u> Carbazones (Diazenecarboxylic hydrazides), Bis(carbazones), and Poly(carbazones) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)</p>	<p>$R-N=N-C(=O)-NR'-N-R''R'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #28:</u> Azo compounds including triazenes with hydroxyl or carboxy or carbonyl substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis[o-(HO-) or alpha- or beta-(HO-)azo compounds], or Poly[o-(HO-) or alpha- or beta-(HO-)azo compounds] (N-O Bidentates, N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)</p>	<p>$R-N=N-R'$ for azo compounds, $R-N=N-NH-R'$ for triazenes, where R, and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-hydroxy or carboxy or carbonyl substituted aryl azo compounds, and alpha- or beta-hydroxy or carboxy or carbonyl alkyl azo compounds.) Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #29:</u> Diazeneformamides, Diazeneacetamides, Bis(diazeneformamides), Bis(diazeneacetamides), Poly(diazeneformamides), and Poly(diazeneacetamides) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)</p>	<p>$R-N=N-C(=O)-NR'R''$ for diazeneformamides, and $R-N=N-CR'R''-C(=O)-NR'''R''''$ for diazeneacetamides, where R, R', R'', R''', and R'''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #30:</u> Diazeneformic acids, Diazeneacetic acids, Bis(diazeneformic acids), Bis(diazeneacetic acids), Poly(diazeneformic acids), Poly(diazeneacetic acids), and derivatives thereof (N-O Bidentates, N-O Tetradentates, N-O Hexadentates)</p>	<p>$R-N=N-C(=O)-O-R'$ for diazeneformic acid, and $R-N=N-CR'R''-C(=O)-O-R'''$ for diazeneacetic acid, where R, R', R'', and R''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>N-O Valence Stabilizer #31:</u> Diazeneformaldehydes, Diazeneacetaldehydes, Bis(diazeneformaldehydes), Bis(diazeneacetaldehydes), Poly(diazeneformaldehydes), and</p>	<p>$R-N=N-C(=O)-R'$ for diazeneformaldehydes, and $R-N=N-CR'R''-C(=O)-R'''$ for diazeneacetaldehydes, where R, R', R'', and R''' represent H, NH₂, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen</p>

Poly(diazeneacetaldehydes) (N-O Bidentates, N-O Tetracentates and N-O Hexacentates)	or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #32:</u> Diazenediformamides, Diazenediacetamides, Bis(diazenediformamides), Bis(diazenediacetamides), Poly(diazenediformamides), and Poly(diazenediacetamides) (N-O Tridentates and N-O Hexacentates)	$RR'-N-C(=O)-N=N-C(=O)-NR''R'''$ for diazenediformamides, and $RR'-N-C(=O)-CR''R'''-N=N-CR''''R'''''-C(=O)-NR''''''R'''''''$ for diazenediacetamides, where R, R', R'', R''', R'''', R''''', and R''''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #33:</u> Diazenediformic acids, Diazenediacetic acids, Bis(diazenediformic acids), Bis(diazenediacetic acids), Poly(diazenediformic acids), Poly(diazenediacetic acids) and derivatives thereof (N-O Tridentates and N-O Hexacentates)	$R-O-C(=O)-N=N-C(=O)-O-R'$ for diazenediformic acid, and $R-O-C(=O)-CR'R''-N=N-CR''''R'''''-C(=O)-O-R''''''$ for diazenediacetic acid, where R, R', R'', R''', R'''', and R'''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #34:</u> Diazenediformaldehydes, Diazenediacetaldehydes, Bis(diazenediformaldehydes), Bis(diazenediacetaldehydes), Poly(diazenediformaldehydes), and Poly(diazenediacetaldehydes) (N-O Tridentates and N-O Hexacentates)	$RC(=O)-N=N-C(=O)-R'$ for diazenediformaldehydes, and $RC(=O)-CR'R''-N=N-CR''''R'''''-C(=O)-R''''''$ for diazenediacetaldehydes, where R, R', R'', R''', R'''', and R'''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #35:</u> Ortho-hydroxy (or -carboxy) Substituted Formazans, Bis(o-hydroxy or -carboxy substituted formazans), and Poly(o-hydroxy or -carboxy substituted formazans) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates)	$R-N=N-CR'=N-NR''R'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-hydroxy or carboxy substituted aryl R derivatives, and beta-hydroxy or carboxy substituted alkyl R derivatives.)

	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #36:</u> Ortho-hydroxy (or -carboxy) Substituted Azines (including ketazines), Bis(o-hydroxy or carboxy substituted azines), and Poly(o-hydroxy or carboxy substituted azines) (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	$RR'C=N-N=CR''R'''$ or $RR'C=N-NR''R'''$ (for ketazines), where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must include ortho-hydroxy or carboxy substituted aryl R derivatives, and beta-hydroxy or carboxy substituted alkyl R derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #37:</u> Schiff Bases with one Imine (C=N) Group and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Bidentates, N-O Tridentates, N-O Tetradentates, N-O Pentadentates, or N-O Hexadentates). Also includes hydrazones with ortho-O substitution.	$RR'C=N-R''$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #38:</u> Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Tridentates, N-O Tetradentates, N-O Pentadentates, or N-O Hexadentates). Also includes hydrazones with ortho-O substitution.	$RR'C=N-R''-N=CR'''R''''$ or $R-N=C-R'-C=N-R'$ or $RC=N-R'-N=CR''$, where R, R', R'', R''', and R'''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #39:</u> Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Tetradentates, N-O Pentadentates, or N-O Hexadentates). Also includes hydrazones with ortho-O substitution.	$N(-R-N=CR'R'')_3$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Must contain ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #40:</u> Silylaminoalcohols (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	$[R-C(NR'R'')]_x-R''-[Si(-OR''')_zR''''_{3-z}]_y$ where R, R', R'', R''', and R'''' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40,

	optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x and y = 1-6, z = 1-3. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #41:</u> Hydroxyalkyl Imines (Imino Alcohols) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates)	$[R-C(=NR')]_x-R''-[C(-OR''')R''''R''''']_y$ or $[R-C(=NR')]_x-R''-[C(=O)R''']_y$, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x and y = 1-6. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #42:</u> Hydroxyaryl Amines and Hydroxyaryl Imines (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates)	$[R(-NR'R'')(-OR''')]$, $[R(-NR'R'')(-C(=O)R''')]$, $[R(-NR'R'')]_xO$, $[R(-NR'R'')]_xO_{2-3}R''''(-OR''')_y$, $[R(-OR')_x]_{2-3}R''(-NR''R''')_y$, and $[R(-NR'R'')]_xO_{2-3}R''(C(=O))_yR''''$ for hydroxyaryl amines; and $[R(-OR')_x]_2NH$ or $[R(-OR')_x]_2NHNH$ for hydroxyaryl imines, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x = 0-2 and y = 1-4. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #43:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms with at least one additional Oxygen Atom Binding Site not in a Ring (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxy, carboxy or carbonyl groups) that constitute O binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #44:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms with at least one additional Oxygen Atom Binding Site not in a Ring	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxy, carboxy, or carbonyl groups) that constitute O

(N-O Bidentates, N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)	binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #45:</u> Five-Membered Heterocyclic Rings containing One or Two Oxygen Atoms with at least one additional Nitrogen Atom Binding Site not in a Ring (N-O Bidentates, N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)	Five membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines, imines, or hydrazides) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #46:</u> Six-Membered Heterocyclic Rings containing One or Two Oxygen Atoms with at least one additional Nitrogen Atom Binding Site not in a Ring (N-O Bidentates, N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)	Six membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines, imines, or hydrazides) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #47:</u> Five-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms with at least one additional Oxygen Atom Binding Site in a Separate Ring (N-O Bidentates, N-O Tridentates, N-O Tetradentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional oxygen-containing rings that constitute O binding sites. Can include other ring systems bound to the N- or O-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P

	atoms. This 5-membered ring(s) and/or additional O-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #48:</u> Six-Membered Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms with at least one additional Oxygen Atom Binding Site in a Separate Ring (N-O Bidentates, N-O Tridentates, N-O Tetradentates)	Six membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional oxygen-containing rings that constitute O binding sites. Can include other ring systems bound to the N- or O-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or additional O-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #49:</u> Two-, Three-, Four-, Six-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) or Oxygen (usually hydroxy, carboxy, or carbonyl groupss) and are not contained in Component Heterocyclic Rings (N-O Bidentates, N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	Macrocyclic ligands containing two, three, four, six, eight, or ten binding sites composed of nitrogen and oxygen to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-O Valence Stabilizer #50:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Oxygen and are contained in Component Heterocyclic Rings (N-O Bidentates, N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)	Macrocyclic ligands containing a total of four, six, eight, or ten heterocyclic rings containing nitrogen or oxygen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N-O Valence Stabilizer #51:</u> Four-, Six-, Eight-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide nitrogen or oxygen binding sites to valence stabilize the central metal ion. Other amine, imine, hydroxy, carboxy, or carbonyl binding sites can also be included in the

Nitrogen or Oxygen and are contained in a Combination of Heterocyclic Rings and Amine, Imine, Hydroxy, Carboxy, or Carbonyl Groups (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates)	macrocyclic ligand, so long as the total number of binding sites is four, six, eight, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-O Valence Stabilizer #1:</u> 1,3-Monothioketones (Monothio-beta-ketonates), 1,3,5-Monothioketones, 1,3,5-Dithioketones, Bis(1,3-Monothioketones), and Poly(1,3-Monothioketones) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$R-C(=S)-CR'R''-C(=O)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #2:</u> Thiomalonamides (Thiomalonodiamides), Bis(thiomalonamides), and Polythiomalonamides (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RR'-N-C(=S)-CR'R''-C(=O)-N-R'''R''''$ where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #3:</u> 2-Thioacylacetamides, 2-Acylthioacetamides, Bis(2-thioacylacetamides), Bis(2acylthioacetamides), Poly(2-thioacylacetamides), and Poly(2-Acylthioacetamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RR'-N-C(=O)-CR'R''-C(=S)-R'''$ for 2-thioacylacetamides, and $RR'-N-C(=S)-CR'R''-C(=O)-R'''$ for 2-acylthioacetamides, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #4:</u> Dithiodicarbonic Diamides, Bis(dithiodicarbonic diamides), and Poly(dithiodicarbonic diamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RR'-N-C(=S)-S-C(=O)-N-R''R'''$ where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #5:</u> Monothiohypophosphoric Acids, Bis(monothiohypophosphoric acids), and	$(R-O)(R'-O)P(=S)-P(=O)(-O-R'')(-O-R''')$; $(R-O)(R'-S)P(=S)-P(=O)(-S-R'')(-O-R''')$; or $(R-S)(R'-S)P(=S)-P(=O)(-S-R'')(-S-R''')$,

Poly(monothiohypophosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to be confused with hypophosphorous acid derivatives (hypophosphites) (R-O-R''R'''P(=O)) which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.
<u>S-O Valence Stabilizer #6:</u> Monothiohypophosphoramides, Bis(monothiohypophosphoramides), and Poly(monothiohypophosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(RR'-N-)(R''R'''-N-)P(=S)-P(=O)(-N-R''''R''''')(-N-R''''''R'''''''), where R, R', R'', R''', R''', R''', R''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms. Note: these ligands are not to be confused with hypophosphorous acid derivatives (hypophosphites) (R-O-R''R'''P(=O)) which are very reducing and therefore unacceptable for stabilization of high valence states in metal ions.
<u>S-O Valence Stabilizer #7:</u> Monothioimidodiphosphoric Acids, Monothiohydrazidodiphosphoric Acids, Bis(monothioimidodiphosphoric Acids), Bis(monothiohydrazidodiphosphoric Acids), Poly(monothioimidodiphosphoric Acid), Poly(monothiohydrazidodiphosphoric Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(R-O-)(R'-O-)P(=S)-NH-P(=O)(-O-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-NH-P(=O)(-S-R'')(-O-R'''); or (R-S-)(R'-S-)P(=S)-NH-P(=O)(-S-R'')(-S-R''') for monothioimidodiphosphoric acids, and -NH-NH- derivatives for monothiohydrazidodiphosphoric acids, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #8:</u> Monothioimidodiphosphoramides, Monothiohydrazidodiphosphoramides, Bis(monothioimidodiphosphoramides), Bis(monothiohydrazidodiphosphoramides), Poly(monothioimidodiphosphoramides), and	(RR'-N-)(R''R'''-N-)P(=S)-NH-P(=O)(-N-R''''R''''')(-N-R''''''R''''''') for monothioimidodiphosphoramides, and -NH-NH- derivatives for monothiohydrazidodiphosphoramides, where R, R', R'', R''', R''', R''', R''', and R'''''' represent H, NH ₂ or any organic functional

Poly(monothiohydrazidodiphosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #9:</u> Monothiodiphosphoramides, Bis(monothiodiphosphoramides), and Poly(monothiodiphosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(RR'-N-)(R''R'''-N-)P(=S)-S-P(=O)(-N-R''''R''''')(-N-R''''''R'''''''), or (RR'-N-)(R''R'''-N-)P(=S)-O-P(=O)(-N-R''''R''''')(-N-R''''''R'''''''), where R, R', R'', R''', R''', R''', R''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #10:</u> Monothiodiphosphoric Acids, Bis(monothiodiphosphoric Acids), Poly(monothiodiphosphoric Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(R-O-)(R'-O-)P(=S)-O-P(=O)(-O-R'')(-O-R'''); (R-O-)(R'-O-)P(=S)-S-P(=O)(-O-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-O-P(=O)(-S-R'')(-O-R'''); (R-O-)(R'-S-)P(=S)-S-P(=O)(-S-R'')(-O-R'''); or (R-S-)(R'-S-)P(=S)-S-P(=O)(-S-R'')(-S-R'''), where R, R', R'', R''', R''', R''', R''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #11:</u> Monothiocarbamates, Bis(monothiocarbamates), and Poly(monothiocarbamates) (including N-hydroxymonothiocarbamates and N-mercaptomonothiocarbamates) (S-O Bidentates, S-O Tridentates, and S-O Tetracentates)	RR'N ⁺ =C(OH)(SH), where R and R' represent H, OH, SH, OR'' (R''=C ₁ -C ₃₀ alkyl or aryl), SR'' (R''=C ₁ -C ₃₀ alkyl or aryl), NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

N Valence Stabilizer #1: Examples of monoamines (N monodentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: ammonia, ethylamine, n-dodecylamine, octylamine, phenylamine, cyclohexylamine, diethylamine, dioctylamine, diphenylamine, dicyclohexylamine, azetidine, hexamethylenetetramine

5 (Urotropin), aziridine, azepine, pyrrolidine, benzopyrrolidine, dibenzopyrrolidine, naphthopyrrolidine, piperidine, benzopiperidine, dibenzopiperidine, naphthopiperidine, azacycloheptane (hexamethyleneimine), aminonorborene, adamantanamine, aniline, benzylamine, toluidine, phenethylamine, xylylene, cumidine, naphthylamine, polyalkylamines, polyanilines, and fluorenediamine.

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N Valence Stabilizer #2: Examples of diamines (N-N bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hydrazine, phenylhydrazine, 1,1-diphenylhydrazine, 1,2-diphenylhydrazine (hydrazobenzene), methanediamine, ethylenediamine (1,2-ethanediamine, en), trimethylenediamine (1,3-

15 propanediamine), putrescine (1,4-butanediamine), cadaverine (1,5-pentanediamine), hexamethylenediamine (1,6-hexanediamine), 2,3-diaminobutane, stilbenediamine (1,2-diphenyl-1,2-ethanediamine), cyclohexane-1,2-diamine, cyclopentane-1,2-diamine, 1,3-diazacyclopentane, 1,3-diazacyclohexane, piperazine, benzopiperazine, dibenzopiperazine, naphthopiperazine, diazepine, thiadiazepine, oxodiazepine, sparteine (lupinidine), 2-

20 (aminomethyl)azacyclohexane, 2-(aminomethyl)piperidine, 2-(aminomethyl)pyrrolidine, 2-(aminomethyl)azetidine, 2-(2-aminoethyl)aziridine, 1,2-diaminobenzene, benzidine, bis(2,2'-piperazino)-1,2-ethene, 1,4-diazabicyclo[2.2.2]octane, naphthylethylenediamine, and 1,2-dianilinoethane.

25 N Valence Stabilizer #3: Examples of triamines (N-N bidentates or N-N tridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-(2-aminoethyl)-1,2-ethanediamine (dien, 2,2-tri); N-(2-aminoethyl)-1,3-propanediamine (2,3-tri); N-(3-aminopropyl)-1,3-propanediamine (3,3-tri, dpt); N-(3-aminopropyl)-1,4-butanediamine (3,4-tri, spermidine); N-(2-aminoethyl)-1,4-butanediamine (2,4-tri); N-(6-hexyl)-

30 1,6-hexanediamine (6,6-tri); 1,3,5-triaminocyclohexane (tach); 2-(aminomethyl)-1,3-propanediamine (tamm); 2-(aminomethyl)-2-methyl-1,3-propanediamine (tame); 2-

(aminomethyl)-2-ethyl-1,3-propanediamine (tamp); 1,2,3-triaminopropane (tap); 2,3-(2-aminoethyl)aziridine; 2,4-(aminomethyl)azetidine; 2,5-(aminomethyl)pyrrolidine; 2,6-(aminomethyl)piperidine; di(2-aminobenzyl)amine; hexahydro-1,3,5-triazine; hexahydro-2,4,6-trimethyl-1,3,5-triazine; and 1,3,5-tris(aminomethyl)benzene.

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N Valence Stabilizer #4: Examples of tetramines (N-N bidentates, N-N tridentates, or N-N tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-(2-aminoethyl)-1,2-ethanediamine (2,2,2-tet, trien (triethylenetetramine)); N,N'-(2-aminoethyl)-1,3-propanediamine (2,3,2-tet, entnen); N,N'-(3-aminopropyl)-1,2-ethanediamine (3,2,3-tet, tnentn); N-(2-aminoethyl)-N'-(3-aminopropyl)-1,2-ethanediamine (2,2,3-tet); N-(2-aminoethyl)-N'-(3-aminopropyl)-1,3-propanediamine (3,3,2-tet); N,N'-(3-aminopropyl)-1,3-propanediamine (3,3,3-tet); N,N'-(3-aminopropyl)-1,4-butanediamine (3,4,3-tet, spermine); tri(aminomethyl)amine (tren); tri(2-aminoethyl)amine (trtn); tri(3-aminopropyl)amine (trbn); 2,2-aminomethyl-1,3-propanediamine (tam); 1,2,3,4-tetraaminobutane (tab); N,N'-(2-aminophenyl)-1,2-ethanediamine; and N,N'-(2-aminophenyl)-1,3-propanediamine.

N Valence Stabilizer #5: Examples of pentamines (N-N bidentates, N-N tridentates, or N-N tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-[N-(2-aminoethyl)-2-aminoethyl]-N'-(2-aminoethyl)-1,2-ethanediamine (2,2,2,2-pent, tetren); N-[N-(3-aminopropyl)-2-aminoethyl]-N'-(3-aminopropyl)-1,2-ethanediamine (3,2,2,3-pent); N-[N-(3-aminopropyl)-3-aminopropyl]-N'-(3-aminopropyl)-1,3-propanediamine (3,3,3,3-pent, caldopentamine); N-[N-(2-aminobenzyl)-2-aminoethyl]-N'-(2-aminopropyl)-1,2-ethanediamine; N-[N-(2-aminoethyl)-2-aminoethyl]-N,N-(2-aminoethyl)amine (trenen); and N-[N-(2-aminopropyl)-2-aminoethyl]-N,N-(2-aminoethyl)amine (4-Me-trenen).

N Valence Stabilizer #6: Examples of hexamines (N-N bidentates, N-N tridentates, N-N tetradentates, or N-N-N-N-N-N hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-[N-(2-aminoethyl)-2-aminoethyl]-1,2-ethanediamine (2,2,2,2,2-hex, linpen); N,N'-[N-(2-aminoethyl)-3-aminopropyl]-

1,2-ethanediamine (2,3,2,3,2-hex); N,N,N',N'-(2-aminoethyl)-1,2-ethanediamine (penten, ten);
N,N,N',N'-(2-aminoethyl)-1-methyl-1,2-ethanediamine (tpn, R-5-Me-penten); N,N,N',N'-(2-
aminoethyl)-1,3-propanediamine (ttn); N,N,N',N'-(2-aminoethyl)-1,4-butanediamine (tbn);
N,N,N',N'-(2-aminoethyl)-1,3-dimethyl-1,3-propanediamine (R,R-tptn, R,S-tptn); N-(2-
5 aminoethyl)-2,2-[N-(2-aminoethyl)aminomethyl-1-propaneamine (sen); and N-(3-aminopropyl)-
2,2-[N-(3-aminopropyl)aminomethyl-1-propaneamine (stn).

N Valence Stabilizer #7a: Examples of 5-membered heterocyclic rings containing one nitrogen
atom (N monodentates) that meet the requirements for use as “wide band” valence stabilizers for
10 Ce⁺⁴ include, but are not limited to: 1-pyrroline, 2-pyrroline, 3-pyrroline, pyrrole, oxazole,
isoxazole, thiazole, isothiazole, azaphosphole, benzopyrroline, benzopyrrole (indole),
benzoxazole, benzisoxazole, benzothiazole, benzisothiazole, benzazaphosphole,
dibenzopyrroline, dibenzopyrrole (carbazole), dibenzoxazole, dibenzisoxazole, dibenzothiazole,
dibenzisothiazole, naphthopyrroline, naphthopyrrole, naphthoxazole, naphthisoxazole,
15 naphthothiazole, naphthisothiazole, naphthazaphosphole, and polypyrroles.

N Valence Stabilizer #7b: Examples of 5-membered heterocyclic rings containing two nitrogen
atoms (N monodentates or N-N bidentates) that meet the requirements for use as “wide band”
valence stabilizers for Ce⁺⁴ include, but are not limited to: pyrazoline, imidazoline, imidazole
20 (ia), pyrazole, oxadiazole, thiadiazole, diazaphosphole, benzopyrazoline, benzimidazoline,
benzimidazole (azindole)(bia)(bz), benzopyrazole (indazole), benzothiadiazole (piazthiole),
benzoxadiazole (benzofurazan), naphthopyrazoline, naphthimidazoline, naphthimidazole,
naphthopyrazole, naphthoxadiazole, naphthothiadiazole, polybenzimidazole, and polyimidazoles
(e.g. polyvinylimidazole (pvi)).

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N Valence Stabilizer #7c: Examples of 5-membered heterocyclic rings containing three nitrogen
atoms (N monodentates, N-N bidentates) that meet the requirements for use as “wide band”
valence stabilizers for Ce⁺⁴ include, but are not limited to: triazole, oxatriazole, thiatriazole,
benzotriazole (bta), tolyltriazole (tt), naphthotriazole, and triazolophthalazine.

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N Valence Stabilizer #7d: Examples of 5-membered heterocyclic rings containing four nitrogen atoms (N monodentates or N-N bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrazole.

- 5 N Valence Stabilizer #8a: Examples of 6-membered heterocyclic rings containing one nitrogen atom (N monodentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: pyridine, picoline, lutidine, -collidine, oxazine, thiazine, azaphosphorin, quinoline, isoquinoline, benzoxazine, benzothiazine, benzazaphosphorin, acridine, phenanthridine, phenothiazine (dibenzothiazine), dibenzoxazine, dibenzazaphosphorin, benzoquinoline (naphthopyridine), naphthoxazine, naphthothiazine, naphthazaphosphorin, and polypyridines.

- N Valence Stabilizer #8b: Examples of 6-membered heterocyclic rings containing two nitrogen atoms (N monodentates or N-N bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: pyrazine, pyridazine, pyrimidine, oxadiazine, thiadiazine, diazaphosphorin, quinoxaline (benzopyrazine), cinnoline (benzo[c]pyridazine), quinazoline (benzopyrimidine), phthalazine (benzo[d]pyridazine), benzoxadiazine, benzothiadiazine, phenazine (dibenzopyrazine), dibenzopyridazine, naphthopyrazine, naphthopyridazine, naphthopyrimidine, naphthoxadiazine, naphthothiadiazine, and polyquinoxalines.

- N Valence Stabilizer #8c: Examples of 6-membered heterocyclic rings containing three nitrogen atoms (N monodentates or N-N bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,3,5-triazine, 1,2,3-triazine, benzo-1,2,3-triazine, naphtho-1,2,3-triazine, oxatriazine, thiatriazine, melamine, and cyanuric acid.

N Valence Stabilizer #8d: Examples of 6-membered heterocyclic rings containing four nitrogen atoms (N monodentates or N-N bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrazine.

N Valence Stabilizer #9a: Examples of 5-membered heterocyclic rings containing one nitrogen atom and having at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(aminomethyl)-3-pyrroline; 2,5-(aminomethyl)-3-pyrroline; 2-(aminomethyl)pyrrole; 2,5-(aminomethyl)pyrrole; 3-(aminomethyl)isoxazole; 2-(aminomethyl)thiazole; 3-(aminomethyl)isothiazole; 2-(aminomethyl)indole; 2-aminobenzoxazole; 2-aminobenzothiazole (abt); 1,8-diaminocarbazole; 2-amino-6-methylbenzothiazole (amebt); 2-amino-6-methoxybenzothiazole (ameobt); and 1,3-diiminoisoindoline.

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N Valence Stabilizer #9b: Examples of 5-membered heterocyclic rings containing two nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

15 2-aminoimidazoline; 1-(3-aminopropyl)imidazoline; 2-aminoimidazole; 1-(3-aminopropyl)imidazole; 4-(2-aminoethyl)imidazole [histamine]; 1-alkyl-4-(2-aminoethyl)imidazole; 3-(2-aminoethyl)pyrazole; 3,5-(2-aminoethyl)pyrazole; 1-(aminomethyl)pyrazole; 2-aminobenzimidazole; 7-(2-aminoethyl)benzimidazole; 1-(3-aminopropyl)benzimidazole; 3-(2-aminoethyl)indazole; 3,7-(2-aminoethyl)indazole; 1-(aminomethyl)indazole; 7-aminobenzothiadiazole; 4-(2-aminoethyl)benzothiadiazole; 7-aminobenzoxadiazole; 4-(2-aminoethyl)benzoxadiazole; ethylenediaminetetra(1-pyrazolylmethane) [edtp]; methylenenitritoltris(2-(1-methyl)benzimidazole) [mntb] [tris(1-methyl-2-benzimidazolylmethane)amine]; bis(alkyl-1-pyrazolylmethane)amine; bis(alkyl-2-(1-pyrazolyl)ethane)amine; bis(N,N-(2-benzimidazolyl)-2-aminoethane)(2-benzimidazolylmethane)amine; bis(1-(3,5-dimethyl)pyrazolylmethane)phenylamine; tris(2-(1-(3,5-dimethyl)pyrazolyl)ethane)amine; 5-(dimethylamino)pyrazole; 5-(dimethylaminomethyl)pyrazole; 2-amino-1,3,4-thiadiazole; and 1-(2-aminoethyl)imidazoline.

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N Valence Stabilizer #9c: Examples of 5-membered heterocyclic rings containing three nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N-N Tridentates, N-N-N-N Tetracentates, or N-N-N-N-N Hexacentates)

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that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-amino-1,2,4-triazole (ata); 3,5-diamino-1,2,4-triazole (dat); 5-amino-1,2,4-triazole; 3-(2-aminoethyl)-1,2,4-triazole; 5-(2-aminoethyl)-1,2,4-triazole; 3,5-(2-aminoethyl)-1,2,4-triazole; 1-(aminomethyl)-1,2,4-triazole; 3,5-(aminomethyl)-4-amino-1,2,4-triazole; 4-(2-aminoethyl)-1,2,3-triazole; 5-(2-aminoethyl)-1,2,3-triazole; 7-aminobenzotriazole; 1-(aminomethyl)-1,2,3-triazole; 1-(2-aminoethyl)-1,2,3-triazole; 4-(3-aminopropyl)benzotriazole; N-(benzotriazolylalkyl)amine; dibenzotriazole-1-ylalkylamine; bis(5-amino-1,2,4-triazol-3-yl); bis(5-amino-1,2,4-triazol-3-yl)alkanes; and 1-(aminomethyl)benzotriazole.

- 10 N Valence Stabilizer #9d: Examples of 5-membered heterocyclic rings containing four nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 5-(2-aminoethyl)-1H-tetrazole; 1-(aminomethyl)-1H-tetrazole; and 1-(2-aminoethyl)-1H-tetrazole.

- N Valence Stabilizer #10a: Examples of 6-membered heterocyclic rings containing one nitrogen atom and having at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminopyridine; 2,6-diaminopyridine; 2-(aminomethyl)pyridine; 2,6-(aminomethyl)pyridine; 2,6-(aminoethyl)pyridine; 2-amino-4-picoline; 2,6-diamino-4-picoline; 2-amino-3,5-lutidine; 2-aminoquinoline; 8-aminoquinoline; 2-aminoisoquinoline; acriflavine; 4-aminophenanthridine; 4,5-(aminomethyl)phenothiazine; 4,5-(aminomethyl)dibenzoxazine; 10-amino-7,8-benzoquinoline; bis(2-pyridylmethane)amine; tris(2-pyridyl)amine; bis(4-(2-pyridyl)-3-azabutane)amine; bis(N,N-(2-(2-pyridyl)ethane)aminomethane)amine; 4-(N,N-dialkylaminomethyl)morpholine; 6-aminonicotinic acid; 8-aminoacridine; and 2-hydrazinopyridine.

- 30 N Valence Stabilizer #10b: Examples of 6-membered heterocyclic rings containing two nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates,

N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminopyrazine; 2,6-diaminopyrazine; 2-(aminomethyl)pyrazine; 2,6-(aminomethyl)pyrazine; 3-(aminomethyl)pyridazine; 3,6-(aminomethyl)pyridazine; 3,6-(2-aminoethyl)pyridazine; 1-aminopyridazine; 1-(aminomethyl)pyridazine; 2-aminopyrimidine; 1-(2-aminoethyl)pyrimidine; 2-aminoquinoxaline; 2,3-diaminoquinoxaline; 2-aminocinnoline; 3-aminocinnoline; 3-(2-aminoethyl)cinnoline; 3,8-(2-aminoethyl)cinnoline; 2-aminoquinazoline; 1-(2-aminoethyl)quinazoline; 1-aminophthalazine; 1,4-(2-aminoethyl)phthalazine; 1,8-(aminomethyl)phenazine; 2-amino-4,6-dimethylpyrimidine (admp); dihydralazine; and hydralazine.

N Valence Stabilizer #10c: Examples of 6-membered heterocyclic rings containing three nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-amino-1,3,5-triazine; 2-(aminomethyl)-1,3,5-triazine; 2,6-(aminomethyl)-1,3,5-triazine; 1-(3-aminopropyl)-1,3,5-triazine; 1,5-(3-aminopropyl)-1,3,5-triazine, polymelamines; melamine; and altretamine.

N Valence Stabilizer #10d: Examples of 6-membered heterocyclic rings containing four nitrogen atoms at least one additional nitrogen atom binding site not contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3,6-(2-aminoethyl)-1,2,4,5-tetrazine; 3,6-(1,3-diamino-2-propyl)-1,2,4,5-tetrazine; and 4,6-(aminomethyl)-1,2,3,5-tetrazine.

N Valence Stabilizer #11a: Examples of 5-membered heterocyclic rings containing one nitrogen atom and having at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-3-pyrroline; 2,2'-bi-2-pyrroline; 2,2'-bi-1-pyrroline; 2,2'-bipyrrole; 2,2',2''-tripyrrole; 3,3'-

biisoxazole; 2,2'-bioxazole; 3,3'-biisothiazole; 2,2'-bithiazole; 2,2'-biindole; 2,2'-bibenzoxazole; 2,2'-bibenzothiazole; bilirubin; biliverdine; and 7-azaindole.

N Valence Stabilizer #11b: Examples of 5-membered heterocyclic rings containing two nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2-imidazoline [2,2'-bi-2-imidazolynyl] [bimd]; 2,2'-biimidazole [2,2'-biimidazolyl] [biimH₂]; 5,5'-bipyrazole; 3,3'-bipyrazole; 4,4'-bipyrazole [4,4'-bipyrazolyl] [bpz]; 2,2'-bioxadiazole; 2,2'-bithiadiazole; 2,2'-bibenzimidazole; 7,7'-biindazole; 5,5'-bibenzofurazan; 5,5'-bibenzothiadiazole; bis-1,2-(2-benzimidazole)ethane; bis(2-benzimidazole)methane; 1,2-(2-imidazolyl)benzene; 2-(2-thiazolyl)benzimidazole; 2-(2-imidazolyl)benzimidazole; benzimidazotriazine; 4-azabenzimidazole; and 2,6-bis(2-benzimidazolyl)pyridine.

N Valence Stabilizer #11c: Examples of 5-membered heterocyclic rings containing three nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 5,5'-bi-1,2,4-triazole [btrz]; 3,3'-bi-1,2,4-triazole; 1,1'-bi-1,2,4-triazole; 1,1'-bi-1,2,3-triazole; 5,5'-bi-1,2,3-triazole; 7,7'-bibenzotriazole; 1,1'-bibenzotriazole; bis(pyridyl)aminotriazole (pat); and 8-azaadenine.

N Valence Stabilizer #11d: Examples of 5-membered heterocyclic rings containing four nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 5,5'-bi-1H-tetrazole; and 1,1'-bi-1H-tetrazole.

N Valence Stabilizer #12a: Examples of 6-membered heterocyclic rings containing one nitrogen atom and having at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements

for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bipyridine [bipy]; 2,2',2''-tripyridine [terpyridine] [terpy]; 2,2',2'',2'''-tetrapyridine [tetrapy]; 6,6'-bi-2-picoline; 6,6'-bi-3-picoline; 6,6'-bi-4-picoline; 6,6'-bi-2,3-lutidine; 6,6'-bi-2,4-lutidine; 6,6'-bi-3,4-lutidine; 6,6'-bi-2,3,4-collidine; 2,2'-biquinoline; 2,2'-biisoquinoline; 3,3'-bibenzoxazine; 3,3'-bibenzothiazine; 1,10-phenanthroline [phen]; 1,8-naphthyridine; bis-1,2-(6-(2,2'-bipyridyl))ethane; bis-1,3-(6-(2,2'-bipyridyl))propane; 3,5-bis(3-pyridyl)pyrazole; 3,5-bis(2-pyridyl)triazole; 1,3-bis(2-pyridyl)-1,3,5-triazine; 1,3-bis(2-pyridyl)-5-(3-pyridyl)-1,3,5-triazine; 2,7-(N,N'-di-2-pyridyl)diaminobenzopyrroline; 2,7-(N,N'-di-2-pyridyl)diaminophthalazine; 2,6-di-(2-benzothiazolyl)pyridine; triazolopyrimidine; 2-(2-pyridyl)imidazoline; 7-azaindole; 1-(2-pyridyl)pyrazole; (1-imidazolyl)(2-pyridyl)methane; 4,5-bis(N,N'-(2-(2-pyridyl)ethyl)iminomethyl)imidazole; bathophenanthroline; 4-(2-benzimidazolyl)quinoline; 1,2-bis(2-pyridyl)ethane; 4,4'-diphenyl-2,2'-dipyridyl; neocuproine; nicotine; and nornicotine.

N Valence Stabilizer #12b: Examples of 6-membered heterocyclic rings containing two nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bipyrazine; 2,2',2''-tripyrazine; 6,6'-bipyridazine; bis(3-pyridazinyl)methane; 1,2-bis(3-pyridazinyl)ethane; 2,2'-bipyrimidine; 2,2'-biquinoxaline; 8,8'-biquinoxaline; bis(3-cinnolyl)methane; bis(3-cinnolyl)ethane; 8,8'-bicinnoline; 2,2'-biquinazoline; 4,4'-biquinazoline; 8,8'-biquinazoline; 2,2'-biphthalazine; 1,1'-biphthalazine; 2-(2-pyridyl)benzimidazole; 8-azapurine; purine; adenine; guanine; hypoxanthine; 2,6-bis(N,N'-(2-(4-imidazolyl)ethyl)iminomethyl)pyridine; 2-(N-(2-(4-imidazolyl)ethyl)iminomethyl)pyridine; adenine (aminopurine); purine; and 2,3-bis(2-pyridyl)pyrazine.

N Valence Stabilizer #12c: Examples of 6-membered heterocyclic rings containing three nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-1,3,5-triazine; 2,2',2''-tri-1,3,5-triazine; 4,4'-bi-1,2,3-triazine; and 4,4'-bibenzo-1,2,3-triazine; 2,4,6-tris(2-pyridyl)-1,3,5-triazine; and benzimidazotriazines.

N Valence Stabilizer #12d: Examples of 6-membered heterocyclic rings containing four nitrogen atoms at least one additional nitrogen atom binding site contained in a ring (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3,3'-bi-1,2,4,5-tetrazine; and

5 4,4'-bi-1,2,3,5-tetrazine.

N Valence Stabilizer #13a: Examples of two-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein both binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in

10 component heterocyclic rings (N-N Bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclobutane ([4]aneN₂); diazacyclopentane ([5]aneN₂); diazacyclohexane ([6]aneN₂); diazacycloheptane ([7]aneN₂); diazacyclooctane ([8]aneN₂); piperazine; benzopiperazine; diazacyclobutene ([4]eneN₂); diazacyclopentene ([5]eneN₂); diazacyclohexene ([6]eneN₂); diazacycloheptene ([7]eneN₂);
15 diazacyclooctene ([8]eneN₂); diazacyclobutadiene ([4]dieneN₂); diazacyclopentadiene ([5]dieneN₂); diazacyclohexadiene ([6]dieneN₂); diazacycloheptadiene ([7]dieneN₂); and diazacyclooctadiene ([8]dieneN₂).

N Valence Stabilizer #13b: Examples of three-membered macrocyclics, macrobicyclics, and

20 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: triazacyclohexane (including hexahydro-1,3,5-triazine) ([6]aneN₃); triazacycloheptane ([7]aneN₃); triazacyclooctane
25 ([8]aneN₃); triazacyclononane ([9]aneN₃); triazacyclodecane ([10]aneN₃); triazacycloundecane ([11]aneN₃); triazacyclododecane ([12]aneN₃); triazacyclohexene ([6]eneN₃); triazacycloheptene ([7]eneN₃); triazacyclooctene ([8]eneN₃); triazacyclononene ([9]eneN₃); triazacyclodecene ([10]eneN₃); triazacycloundecene ([11]eneN₃); triazacyclododecene ([12]eneN₃);
triazacyclohexatriene ([6]trieneN₃); triazacycloheptatriene ([7]trieneN₃); triazacyclooctatriene
30 ([8]trieneN₃); triazacyclononatriene ([9]trieneN₃); triazacyclodecatriene ([10]trieneN₃); triazacycloundecatriene ([11]trieneN₃); and triazacyclododecatriene ([12]trieneN₃).

N Valence Stabilizer #13c: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tetradentates) that meet the requirements for use as “wide

- 5 band” valence stabilizers for Ce^{+4} include, but are not limited to: tetraazacyclooctane ([8]aneN₄); tetraazacyclononane ([9]aneN₄); tetraazacyclodecane ([10]aneN₄); tetraazacycloundecane ([11]aneN₄); tetraazacyclododecane ([12]aneN₄); tetraazacyclotridecane ([13]aneN₄); tetraazacyclotetradecane ([14]aneN₄); tetraazacyclopentadecane ([15]aneN₄); tetraazacyclohexadecane ([16]aneN₄); tetraazacycloheptadecane ([17]aneN₄);
- 10 tetraazacyclooctadecane ([18]aneN₄); tetraazacyclononadecane ([19]aneN₄); tetraazacycloeicosane ([20]aneN₄); tetraazacyclooctadiene ([8]dieneN₄); tetraazacyclononadiene ([9]dieneN₄); tetraazacyclodecadiene ([10]dieneN₄); tetraazacycloundecadiene ([11]dieneN₄); tetraazacyclododecadiene ([12]dieneN₄); tetraazacyclotridecadiene ([13]dieneN₄); tetraazacyclotetradecadiene ([14]dieneN₄); tetraazacyclopentadecadiene ([15]dieneN₄);
- 15 tetraazacyclohexadecadiene ([16]dieneN₄); tetraazacycloheptadecadiene ([17]dieneN₄); tetraazacyclooctadecadiene ([18]dieneN₄); tetraazacyclononadecadiene ([19]dieneN₄); tetraazacycloeicosadiene ([20]dieneN₄); tetraazacyclooctatetradiene ([8]tetradieneN₄); tetraazacyclononatetradiene ([9]tetradieneN₄); tetraazacyclodecatetradiene ([10]tetradieneN₄); tetraazacycloundecatetradiene ([11]tetradieneN₄); tetraazacyclododecatetradiene ([12]tetradieneN₄); tetraazacyclotridecatetradiene ([13]tetradieneN₄); tetraazacyclotetradecatetradiene ([14]tetradieneN₄); tetraazacyclopentadecatetradiene ([15]tetradieneN₄); tetraazacyclohexadecatetradiene ([16]tetradieneN₄); tetraazacycloheptadecatetradiene ([17]tetradieneN₄); tetraazacyclooctadecatetradiene ([18]tetradieneN₄); tetraazacyclononadecatetradiene ([19]tetradieneN₄); and
- 25 tetraazacycloeicosatetradiene ([20]tetradieneN₄).

N Valence Stabilizer #13d: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that

30 meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not

- limited to: hexaazacyclododecane ([12]aneN₆); hexaazacyclotridecane ([13]aneN₆);
 hexaazacyclotetradecane ([14]aneN₆); hexaazacyclopentadecane ([15]aneN₆);
 hexaazacyclohexadecane ([16]aneN₆); hexaazacycloheptadecane ([17]aneN₆);
 hexaazacyclooctadecane ([18]aneN₆); hexaazacyclononadecane ([19]aneN₆);
- 5 hexaazacycloeicosane ([20]aneN₆); hexaazacycloheneicosane ([21]aneN₆);
 hexaazacyclodocosane ([22]aneN₆); hexaazacyclotricosane ([23]aneN₆);
 hexaazacyclotetracosane ([24]aneN₆); hexaazacyclododecatriene ([12]trieneN₆);
 hexaazacyclotridecatriene ([13]trieneN₆); hexaazacyclotetradecatriene ([14]trieneN₆);
 hexaazacyclopentadecatriene ([15]trieneN₆); hexaazacyclohexadecatriene ([16]trieneN₆);
- 10 hexaazacycloheptadecatriene ([17]trieneN₆); hexaazacyclooctadecatriene ([18]trieneN₆);
 hexaazacyclononadecatriene ([19]trieneN₆); hexaazacycloeicosatriene ([20]trieneN₆);
 hexaazacycloheneicosatriene ([21]trieneN₆); hexaazacyclodocosatriene ([22]trieneN₆);
 hexaazacyclotricosatriene ([23]trieneN₆); and hexaazacyclotetracosatriene ([24]trieneN₆).
- 15 N Valence Stabilizer #13e: Examples of eight-membered macrocyclics, macrobicyclics, and
 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
 binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in
 component heterocyclic rings (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that
 meet the requirements for use as “wide band” valence stabilizers for Ce⁺⁴ include, but are not
- 20 limited to: octaazacyclohexadecane ([16]aneN₈); octaazacycloheptadecane ([17]aneN₈);
 octaazacyclooctadecane ([18]aneN₈); octaazacyclononadecane ([19]aneN₈);
 octaazacycloeicosane ([20]aneN₈); octaazacycloheneicosane ([21]aneN₈); octaazacyclodocosane
 ([22]aneN₈); octaazacyclotricosane ([23]aneN₈); octaazacyclotetracosane ([24]aneN₈);
 octaazacyclohexadecatetradene ([16]tetradeneN₈); octaazacycloheptadecatetradene
- 25 ([17]tetradeneN₈); octaazacyclooctadecatetradene ([18]tetradeneN₈);
 octaazacyclononadecatetradene ([19]tetradeneN₈); octaazacycloeicosatetradene
 ([20]tetradeneN₈); octaazacycloheneicosatetradene ([21]tetradeneN₈);
 octaazacyclodocosatetradene ([22]tetradeneN₈); octaazacyclotricosatetradene
 ([23]tetradeneN₈); and octaazacyclotetracosatetradene ([24]tetradeneN₈).

- N Valence Stabilizer #13f: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that
- 5 meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: decaazacycloeicosane ([20]aneN₁₀); decaazacycloheneicosane ([21]aneN₁₀); decaazacyclodocosane ([22]aneN₁₀); decaazacyclotricosane ([23]aneN₁₀); decaazacyclotetracosane ([24]aneN₁₀); decaazacyclopentacosane ([25]aneN₁₀); decaazacyclohexacosane ([26]aneN₁₀); decaazacycloheptacosane ([27]aneN₁₀);
- 10 decaazacyclooctacosane ([28]aneN₁₀); decaazacyclononacosane ([29]aneN₁₀); decaazacyclotriacontane ([30]aneN₁₀); decaazacycloeicosapentadiene ([20]pentadieneN₁₀); decaazacycloheneicosapentadiene ([21]pentadieneN₁₀); decaazacyclodocosapentadiene ([22]pentadieneN₁₀); decaazacyclotricosapentadiene ([23]pentadieneN₁₀); decaazacyclotetracosapentadiene ([24]pentadieneN₁₀); decaazacyclopentacosapentadiene
- 15 ([25]pentadieneN₁₀); decaazacyclohexacosapentadiene ([26]pentadieneN₁₀); decaazacycloheptacosapentadiene ([27]pentadieneN₁₀); decaazacyclooctacosapentadiene ([28]pentadieneN₁₀); decaazacyclononacosapentadiene ([29]pentadieneN₁₀); and decaazacyclotriacontapentadiene ([30]pentadieneN₁₀).
- 20 N Valence Stabilizer #14a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: porphyrins (including
- 25 tetraphenylporphine (tpp); “picket fence” porphyrins, “picket tail” porphyrins, “bis pocket” porphyrins, “capped” porphyrins, cyclophane porphyrins, “pagoda” porphyrins, “pocket” porphyrins, “pocket tail” porphyrins, cofacial diporphyrins, “strapped” porphyrins, “hanging base” porphyrins, bridged porphyrins, chelated mesoporphyrins, homoporphyrins, chlorophylls, and pheophytins); porphodimethanes; porphyrinogens; chlorins; bacteriochlorins;
- 30 isobacteriochlorins; corroles; corrins and corrinoids; didehydrocorrins; tetrahydrocorrins; hexahydrocorrins; octahydrocorrins; tetraoxazoles; tetraisoaxazoles; tetrathiazoles;

tetraisothiazoles; tetraazaphospholes; tetraimidazoles; tetrapyrazoles; tetraoxadiazoles; tetrathiadiazoles; tetradiazaphospholes; tetratriazoles; tetraoxatriazoles; tetrathiatrizoles; coproporphyrin; etioporphyrin; and hematoporphyrin.

- 5 N Valence Stabilizer #14b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tridentates, N-N Tetridentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 10 hexaphyrins (hexapyrroles); hexaoxazoles; hexaisooxazoles; hexathiazoles; hexaisothiazoles; hexaazaphospholes; hexaimidazoles; hexapyrazoles; hexaoxadiazoles; hexathiadiazoles; hexadiazaphospholes; hexatriazoles; hexaoxatriazoles; and hexathiatrizoles.

- N Valence Stabilizer #14c: Examples of eight-membered macrocyclics, macrobicyclics, and
- 15 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tridentates, N-N Tetridentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 20 octaphyrins (octapyrroles); octaoxazoles; octaisooxazoles; octathiazoles; octaisothiazoles; octaazaphospholes; octaimidazoles; octapyrazoles; octaoxadiazoles; octathiadiazoles; octadiazaphospholes; octatriazoles; octaoxatriazoles; and octathiatrizoles.

- N Valence Stabilizer #14d: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
- 25 ten binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tridentates, N-N Tetridentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 30 decaphyrins (decapyrroles); decaoxazoles; decaisooxazoles; decathiazoles; decaisothiazoles; decaazaphospholes; decaimidazoles; decapyrazoles; decaoxadiazoles; decathiadiazoles; decadiazaphospholes; decatriazoles; decaoxatriazoles; and decathiatrizoles.

N Valence Stabilizer #15a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: porphyrazines; octahydrodiazaporphyrins; phthalocyanines; naphthalocyanines; anthracocyanines; and tetraazaporphyrins

N Valence Stabilizer #15b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazahexaphyrins; tetraazahexaphyrins; hexaazahexaphyrins; diazahexapyrazoles; tetraazahexapyrazoles; hexaazahexapyrazoles; diazahexamidazoles; tetraazahexamidazoles; and hexaazahexamidazoles.

N Valence Stabilizer #15c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazaoctaphyrins; tetraazaoctaphyrins; hexaazaoctaphyrins; octaazaoctaphyrins; diazaoctapyrazoles; tetraazaoctapyrazoles; hexaazaoctapyrazoles; octaazaoctapyrazoles; diazaoctaimidazoles; tetraazaoctaimidazoles; hexaazaoctaimidazoles; and octaazaoctaimidazoles.

N Valence Stabilizer #15d: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetradentates, or N-N

Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazadecaphyrins; tetraazadecaphyrins; hexaazadecaphyrins; octaazadecaphyrins; decaazadecaphyrins; diazadecapyrazoles; tetraazadecapyrazoles; hexaazadecapyrazoles; octaazadecapyrazoles; decaazadecapyrazoles; diazadecaimidazoles; 5 tetraazadecaimidazoles; hexaazadecaimidazoles; octaazadecaimidazoles; and decaazadecaimidazoles.

N Valence Stabilizer #16a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all 10 four binding sites are composed of nitrogen and are contained in component 6-membered heterocyclic rings (N-N Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclotetrapyridines; cyclotetraoxazines; cyclotetrathiazines; cyclotetraphosphorins; cyclotetraquinolines; cyclotetrapyrazines; cyclotetrapyridazines; cyclotetrapyrimidines; cyclotetraoxadiazines; 15 cyclotetrathiadiazines; cyclotetradiazaphosphorins; cyclotetraquinoxalines; cyclotettriazines; cyclotetrathiatriazines; and cyclotetraoxatriazines.

N Valence Stabilizer #16b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all 20 six binding sites are composed of nitrogen and are contained in component 6-membered heterocyclic rings (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclosexipyridines; cyclosexioxazines; cyclosexithiazines; cyclosexiphosphorins; cyclosexiquinolines; cyclosexipyrazines; cyclosexipyridazines; cyclosexipyrimidines; 25 cyclosexioxadiazines; cyclosexithiadiazines; cyclosexidiazaphosphorins cyclosexiquinoxalines; cyclosexitriazines; cyclosexithiatriazines; and cyclosexioxatriazines.

N Valence Stabilizer #16c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all 30 six binding sites are composed of nitrogen and are contained in component 6-membered heterocyclic rings (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates) that meet the

requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclooctapyridines; cyclooctaoxazines; cyclooctathiazines; cyclooctaphosphorins; cyclooctaquinolines; cyclooctapyrazines; cyclooctapyridazines; cyclooctapyrimidines; cyclooctaoxadiazines; cyclooctathiadiazines; cyclooctadiazaphosphorins; cyclooctaquinoxalines; 5 cyclooctatriazines; cyclooctathiatrizines; and cyclooctaoxatriazines.

N Valence Stabilizer #16d: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of nitrogen and are contained in component 6-membered 10 heterocyclic rings (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclodecapyridines; cyclodecaoxazines; cyclodecathiazines; cyclodecaphosphorins; cyclodecaquinolines; cyclodecapyrazines; cyclodecapyridazines; cyclodecapyrimidines; cyclodecaoxadiazines; cyclodecathiadiazines; cyclodecadiazaphosphorins; 15 cyclodecaquinoxalines; cyclodecatrizines; cyclodecathiatrizines; and cyclodecaoxatriazines.

N Valence Stabilizer #17a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of nitrogen and are contained in a combination of 6-membered 20 heterocyclic rings and amine or imine groups (N-N Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclotetrapyridines; tetraazacyclotetrapyridines; diazacyclotetraquinolines; tetraazacyclotetraquinolines; diazacyclotetrapyrazines; tetraazacyclotetrapyrazines; diazacyclotetrapyridazines; tetraazacyclotetrapyridazines; diazacyclotetrapyrimidines; 25 tetraazacyclotetrapyrimidines; diazacyclotettriazines; and tetraazacyclotettriazines.

N Valence Stabilizer #17b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of nitrogen and are contained in a combination of 6-membered 30 heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

include, but are not limited to: diazacyclohexipyridines; triazacyclohexipyridines; diazacyclohexiquinolines; triazacyclohexiquinolines; diazacyclohexipyrazines; triazacyclohexipyrazines; diazacyclohexipyrizidazines; triazacyclohexipyrizidazines; diazacyclohexipyrizidines; triazacyclohexipyrizidines; diazacyclohexitriazines; and
5 triazacyclohexitriazines.

N Valence Stabilizer #17c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of nitrogen and are contained in a combination of 6-membered
10 heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetridentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclooctapyridines; tetraazacyclooctapyridines; diazacyclooctaquinolines; tetraazacyclooctaquinolines; diazacyclooctapyrazines; tetraazacyclooctapyrazines; diazacyclooctapyridazines; tetraazacyclooctapyridazines; diazacyclooctapyrimidines; tetraazacyclooctapyrimidines; diazacyclooctatriazines; and
15 tetraazacyclooctatriazines.

N Valence Stabilizer #17d: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of nitrogen and are contained in a combination of 6-membered
20 heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetridentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclodecapyrizidines; pentaazacyclodecapyrizidines; diazacyclodecaquinolines; pentaazacyclodecaquinolines; diazacyclodecapyrizines; pentaazacyclodecapyrizines; diazacyclodecapyrizidazines; pentaazacyclodecapyrizidazines; diazacyclodecapyrizidines; pentaazacyclodecapyrizidines; diazacyclodecatriazines; and
25 pentaazacyclodecatriazines.

N Valence Stabilizer #18: Examples of amidines and diamidines (N-N bidentates or N-N Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-dimethylformamidine; N,N'-diethylformamidine; N,N'-

diisopropylformamidine; N,N'-dibutylformamidine; N,N'-diphenylformamidine; N,N'-dibenzylformamidine; N,N'-dinaphthylformamidine; N,N'-dicyclohexylformamidine; N,N'-dinorbornylformamidine; N,N'-diadamantylformamidine; N,N'-dianthraquinonylformamidine; N,N'-dimethylacetamidine; N,N'-diethylacetamidine; N,N'-diisopropylacetamidine; N,N'-dibutylacetamidine; N,N'-diphenylacetamidine; N,N'-dibenzylacetamidine; N,N'-dinaphthylacetamidine; N,N'-dicyclohexylacetamidine; N,N'-dinorbornylacetamidine; N,N'-diadamantylacetamidine; N,N'-dimethylbenzamidine; N,N'-diethylbenzamidine; N,N'-diisopropylbenzamidine; N,N'-dibutylbenzamidine; N,N'-diphenylbenzamidine; N,N'-dibenzylbenzamidine; N,N'-dinaphthylbenzamidine; N,N'-dicyclohexylbenzamidine; N,N'-dinorbornylbenzamidine; N,N'-diadamantylbenzamidine; N,N'-dimethyltoluamidine; N,N'-diethyltoluamidine; N,N'-diisopropyltoluamidine; N,N'-dibutyltoluamidine; N,N'-diphenyltoluamidine; N,N'-dibenzyltoluamidine; N,N'-dinaphthyltoluamidine; N,N'-dicyclohexyltoluamidine; N,N'-dinorbornyltoluamidine; N,N'-diadamantyltoluamidine; oxalic diamidine; malonic diamidine; succinic diamidine; glutaric diamidine; adipic diamidine; pimelic diamidine; suberic diamidine; phthalic diamidine; terephthalic diamidine; isophthalic diamidine; piperazine diamidine; 2-iminopyrrolidine; 2-iminopiperidine; amidinobenzamide; benzamidine; chloroazodin; and debrisquin.

N Valence Stabilizer #19: Examples of biguanides (imidodicarbonimidic diamides),

biguanidines, imidotricarbonimidic diamides, imidotetracarbonimidic diamides, dibiguanides, bis(biguanidines), polybiguanides, and poly(biguanidines) (N-N bidentates, N-N tridentates, N-N tetradentates, and N-N hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: biguanide (bigH); biguanidine, methylbiguanide; ethylbiguanide; isopropylbiguanide; butylbiguanide; benzylbiguanide; phenylbiguanide; tolylbiguanide; naphthylbiguanide; cyclohexylbiguanide; norbornylbiguanide; adamantylbiguanide; dimethylbiguanide; diethylbiguanide; diisopropylbiguanide; dibutylbiguanide; dibenzylbiguanide; diphenylbiguanide; ditolylbiguanide; dinaphthylbiguanide; dicyclohexylbiguanide; dinorbornylbiguanide; diadamantylbiguanide; ethylenedibiguanide; propylenedibiguanide; tetramethylenedibiguanide; pentamethylenedibiguanide; hexamethylenedibiguanide; heptamethylenedibiguanide; octamethylenedibiguanide; phenylenedibiguanide; piperazinedibiguanide; oxalaldibiguanide; malonyldibiguanide;

succinyldibiguanide; glutaryldibiguanide; adipyldibiguanide; pimelyldibiguanide; suberyldibiguanide; phthalyldibiguanide; paludrine; polyhexamethylene biguanide; 2-guanidinothiazole; 2-guanidinooxazole; 2-guanidinoimidazole; 3-guanidinopyrazole; 3-guanidino-1,2,4-triazole; 5-guanidinotetrazole; alexidine; buformin; and moroxydine.

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N Valence Stabilizer #20: Examples of diamidinomethanes, bis(diamidinomethanes), and poly(diamidinomethanes) (N-N bidentates, N-N tridentates, N-N tetradentates, and N-N hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diamidinomethane; N-methyldiamidinomethane; N-

- 10 ethyldiamidinomethane; N-isopropyldiamidinomethane; N-butyldiamidinomethane; N-benzoyldiamidinomethane; N-phenyldiamidinomethane; N-tolyldiamidinomethane; N-naphthyldiamidinomethane; N-cyclohexyldiamidinomethane; N-norbornyldiamidinomethane; N-adamantyldiamidinomethane; dimethyldiamidinomethane; diethyldiamidinomethane; diisopropyldiamidinomethane; dibutyldiamidinomethane; dibenzoyldiamidinomethane;
- 15 diphenyldiamidinomethane; ditolyldiamidinomethane; dinaphthyldiamidinomethane; dicyclohexyldiamidinomethane; dinorbornyldiamidinomethane; diadamantyldiamidinomethane; ethylenebisdiamidinomethane; propylenebisdiamidinomethane; tetramethylenebisdiamidinomethane; pentamethylenebisdiamidinomethane; hexamethylenebisdiamidinomethane; heptamethylenebisdiamidinomethane;
- 20 octamethylenebisdiamidinomethane; phenylenebisdiamidinomethane; piperazinebisdiamidinomethane; oxalylbisdiamidinomethane; malonylbisdiamidinomethane; succinylbisdiamidinomethane; glutarylbidiamidinomethane; phthalylbidiamidinomethane; 2-amidinomethylthiazole; 2-amidinomethyloxazole; 2-amidinomethylimidazole; 3-amidinomethylpyrazole; 3-amidinomethyl-1,2,4-triazole; and 5-amidinomethyltetrazole.

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N Valence Stabilizer #21: Examples of imidoylguanidines, amidinoguanidines, bis(imidoylguanidines), bis(amidinoguanidines), poly(imidoylguanidines), and poly(amidinoguanidines) (N-N bidentates, N-N tridentates, N-N tetradentates, and N-N hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

- 30 include, but are not limited to: acetimidoylguanidine; amidinoguanidine, benzimidoylguanidine; cyclohexylimidoylguanidine; pentafluorobenzimidoylguanidine; 2-N-imidoylaminothiazole; 2-

N-imidoylaminooxazole; 2-N-imidoylaminoimidazole; 3-N-imidoylaminopyrazole; 3-N-imidoylamino-1,2,4-triazole; and 5-N-imidoylaminotetrazole.

N Valence Stabilizer #22: Examples of diformamidine oxides (dicarbonimidic diamides),

- 5 tricarbonimidic diamides, tetracarbonimidic diamides, bis(diformamidine oxides), and poly(diformamidine oxides) (N-N bidentates, N-N tridentates, or N-N tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diformamidine oxide; methyl diformamidine oxide; ethyl diformamidine oxide; isopropyl diformamidine oxide; butyl diformamidine oxide; benzyl diformamidine oxide;
- 10 phenyl diformamidine oxide; tolyl diformamidine oxide; naphthyl diformamidine oxide; cyclohexyl diformamidine oxide; norbornyl diformamidine oxide; adamantyl diformamidine oxide; dimethyl diformamidine oxide; diethyl diformamidine oxide; diisopropyl diformamidine oxide; dibutyl diformamidine oxide; dibenzyl diformamidine oxide; diphenyl diformamidine oxide; ditolyl diformamidine oxide; dinaphthyl diformamidine oxide; dicyclohexyl diformamidine
- 15 oxide; dinorbornyl diformamidine oxide; diadamantyl diformamidine oxide; 2-O-amidinohydroxythiazole; 2-O-amidinohydroxyoxazole; 2-O-amidinohydroxyimidazole; 3-O-amidinohydroxypyrazole; 3-O-amidinohydroxy-1,2,4-triazole; and 5-O-amidinohydroxytetrazole.

- 20 N Valence Stabilizer #23: Examples of diformamidine sulfides (thiodicarbonimidic diamides), thiotricarbonimidic diamides, thiotetracarbonimidic diamides, bis(diformamidine sulfides), and poly(diformamidine sulfides) (N-N bidentates, N-N tridentates, or N-N tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diformamidine sulfide; methyl diformamidine sulfide; ethyl diformamidine sulfide;
- 25 isopropyl diformamidine sulfide; butyl diformamidine sulfide; benzyl diformamidine sulfide; phenyl diformamidine sulfide; tolyl diformamidine sulfide; naphthyl diformamidine sulfide; cyclohexyl diformamidine sulfide; norbornyl diformamidine sulfide; adamantyl diformamidine sulfide; dimethyl diformamidine sulfide; diethyl diformamidine sulfide; diisopropyl diformamidine sulfide; dibutyl diformamidine sulfide; dibenzyl diformamidine sulfide; diphenyl diformamidine
- 30 sulfide; ditolyl diformamidine sulfide; dinaphthyl diformamidine sulfide; dicyclohexyl diformamidine sulfide; dinorbornyl diformamidine sulfide;

diadamantyldiformamidine sulfide; phenylthiobisformamidine; 2-S-amidinomercaptothiazole; 2-S-amidinomercaptooxazole; 2-S-amidinomercaptoimidazole; 3-S-amidinomercaptopyrazole; 3-S-amidinomercapto-1,2,4-triazole; and 5-S-amidinomercaptotetrazole.

- 5 N Valence Stabilizer #24: Examples of imidodicarbonimidic acids, diimidodicarbonimidic acids, imidotricarbonimidic acids, imidotetracarbonimidic acids, and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: imidodicarbonimidic acid, diimidodicarbonimidic acid, imidotricarbonimidic acid,
- 10 imidotetracarbonimidic acid; O-methylimidodicarbonimidic acid; O-ethylimidodicarbonimidic acid; O-isopropylimidodicarbonimidic acid; O-phenylimidodicarbonimidic acid; O-benzylimidodicarbonimidic acid; O-cyclohexylimidodicarbonimidic acid; O-naphthylimidodicarbonimidic acid; O-norbornylimidodicarbonimidic acid; O-adamantylimidodicarbonimidic acid; O,O'-dimethylimidodicarbonimidic acid; O,O'-
- 15 diethylimidodicarbonimidic acid; O,O'-diisopropylimidodicarbonimidic acid; O,O'-diphenylimidodicarbonimidic acid; O,O'-dibenzylimidodicarbonimidic acid; O,O'-dicyclohexylimidodicarbonimidic acid; O,O'-dinaphthylimidodicarbonimidic acid; O,O'-dinorbornylimidodicarbonimidic acid; and O,O'-diadamantylimidodicarbonimidic acid.
- 20 N Valence Stabilizer #25: Examples of thioimidodicarbonimidic acids, thiodiimidodicarbonimidic acids, thioimidotricarbonimidic acids, thioimidotetracarbonimidic acids, and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: thioimidodicarbonimidic acid, thiodiimidodicarbonimidic acid,
- 25 thioimidotricarbonimidic acid, thioimidotetracarbonimidic acid; O-methylthioimidodicarbonimidic acid; O-ethylthioimidodicarbonimidic acid; O-isopropylthioimidodicarbonimidic acid; O-phenylthioimidodicarbonimidic acid; O-benzylthioimidodicarbonimidic acid; O-cyclohexylthioimidodicarbonimidic acid; O-naphthylthioimidodicarbonimidic acid; O-norbornylthioimidodicarbonimidic acid; O-
- 30 adamantylthioimidodicarbonimidic acid; O,O'-dimethylthioimidodicarbonimidic acid; O,O'-diethylthioimidodicarbonimidic acid; O,O'-diisopropylthioimidodicarbonimidic acid; O,O'-

diphenylthioimidodicarbonimidic acid; O,O'-dibenzylthioimidodicarbonimidic acid; O,O'-dicyclohexylthioimidodicarbonimidic acid; O,O'-dinaphthylthioimidodicarbonimidic acid; O,O'-dinorbornylthioimidodicarbonimidic acid; and O,O'-diadamantylthioimidodicarbonimidic acid.

- 5 N Valence Stabilizer #26: Examples of diimidoylimines, diimidoylhydrazides, bis(diimidoylimines), bis(diimidoylhydrazides), poly(diimidoylimines), and poly(diimidoylhydrazides) (N-N Tridentates and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diacetimidoylimine; dibenzimidoylimine; and dicyclohexylimidoylimine.
- 10 N Valence Stabilizer #27: Examples of imidosulfamides, diimidosulfamides, bis(imidosulfamides), bis(diimidosulfamides), poly(imidosulfamides), and poly(diimidosulfamides) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}
- 15 include, but are not limited to: imidosulfamidic acid, diimidosulfamidic acid; O-phenylimidosulfamide; O-benzylimidosulfamide; N-phenylimidosulfamide; N-benzylimidosulfamide; O-phenyldiimidosulfamide; O-benzilydiimidosulfamide; N-phenyldiimidosulfamide; and N-benzilydiimidosulfamide.
- 20 N Valence Stabilizer #28: Examples of phosphoramidimidic triamides, bis(phosphoramidimidic triamides), and poly(phosphoramidimidic triamides) and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidimidic triamide; N-phenylphosphoramidimidic triamide; N-benzylphosphoramidimidic triamide; N-
- 25 naphthylphosphoramidimidic triamide; N-cyclohexylphosphoramidimidic triamide; N-norbornylphosphoramidimidic triamide; N,N'-diphenylphosphoramidimidic triamide; N,N'-dibenzylphosphoramidimidic triamide; N,N'-dinaphthylphosphoramidimidic triamide; N,N'-dicyclohexylphosphoramidimidic triamide; and N,N'-dinorbornylphosphoramidimidic triamide.
- 30 N Valence Stabilizer #29: Examples of phosphoramidimidic acid, phosphorodiamidimidic acid, bis(phosphoramidimidic acid), bis(phosphorodiamidimidic acid), poly(phosphoramidimidic

acid), poly(phosphorodiamidimidic acid), and derivatives thereof (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidimidic acid, phosphorodiamidimidic acid, O-phenylphosphoramidimidic acid; O-

- 5 benzylphosphoramidimidic acid; O-naphthylphosphoramidimidic acid; O-cyclohexylphosphoramidimidic acid; O-norbornylphosphoramidimidic acid; O,O'-diphenylphosphoramidimidic acid; O,O'-dibenzylphosphoramidimidic acid; O,O'-dinaphthylphosphoramidimidic acid; O,O'-dicyclohexylphosphoramidimidic acid; and O,O'-dinorbornylphosphoramidimidic acid.

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N Valence Stabilizer #30: Examples of phosphoramidimidodithioic acid, phosphorodiamidimidodithioic acid, bis(phosphoramidimidodithioic acid), bis(phosphorodiamidimidodithioic acid), poly(phosphoramidimidodithioic acid), poly(phosphorodiamidimidodithioic acid), and derivatives thereof (N-N Bidentates, N-N

- 15 Tridentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidimidodithioic acid, phosphorodiamidimidodithioic acid, S-phenylphosphoramidimidodithioic acid; S-benzylphosphoramidimidodithioic acid; S-naphthylphosphoramidimidodithioic acid; S-cyclohexylphosphoramidimidodithioic acid; S-
- 20 norbornylphosphoramidimidodithioic acid; S,S'-diphenylphosphoramidimidodithioic acid; S,S'-dibenzylphosphoramidimidodithioic acid; S,S'-dinaphthylphosphoramidimidodithioic acid; S,S'-dicyclohexylphosphoramidimidodithioic acid; and S,S'-dinorbornylphosphoramidimidodithioic acid.

- 25 N Valence Stabilizer #31: Examples of azo compounds with amino, imino, oximo, diazeno, or hydrazido substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, bis[o-(H₂N-) or alpha- or beta-(H₂N-)azo compounds], or poly[o-(H₂N-) or alpha- or beta-(H₂N-)azo compounds) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not
- 30 limited to: o-aminoazobenzene; o,o'-diaminoazobenzene; (2-pyridine)azobenzene; 1-phenylazo-2-naphthylamine; pyridineazo-2-naphthol (PAN); pyridineazoresorcinol (PAR); o-hydroxy-o'-

(beta-aminoethylamino)azobenzene; Benzopurpurin 4B; Congo Red; Fat Brown RR; benzopurpurin; Congo Red; Direct Red 75; Mordant Brown 48; Nitro Red; 2-imidazolylazobenzene; 2-benzimidazolylazobenzene; 3-pyrazolylazobenzene; 3-(1,2,4-triazolyl)azobenzene; 2-pyridylazobenzene; 2-pyrazinylazobenzene; and 2-pyrimidinylazobenzene.

N Valence Stabilizer #32: Examples of diazeneformimidamides (diazeneamidines), diazeneacetimidamides (diazene-alpha-amidinoalkanes(alkenes)), bis(diazeneformimidamides), bis(diazeneacetimidamides), poly(diazeneformimidamides), and poly(diazeneacetimidamides) (N-N Bidentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformimidamide (diazeneamidine); diazeneacetimidamide (diazene-alpha-amidinomethane); phenyldiazeneformimidamide; triphenyldiazeneformimidamide; phenyldiazeneacetimidamide; and triphenyldiazeneacetimidamide.

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N Valence Stabilizer #33: Examples of diazeneformimidic acid, diazeneacetimidic acid, bis(diazeneformimidic acid), bis(diazeneacetimidic acid), poly(diazeneformimidic acid), poly(diazeneacetimidic acid), and derivatives thereof (N-N Bidentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformimidic acid, diazeneacetimidic acid, phenyldiazeneformimidic acid, diphenyldiazeneformimidic acid, phenyldiazeneacetimidic acid, and diphenyldiazeneacetimidic acid.

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N Valence Stabilizer #34: Examples of diazeneformimidothioic acid, diazeneacetimidothioic acid, bis(diazeneformimidothioic acid), bis(diazeneacetimidothioic acid), poly(diazeneformimidothioic acid), poly(diazeneacetimidothioic acid), and derivatives thereof (N-N Bidentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformimidothioic acid, diazeneacetimidothioic acid, phenyldiazeneformimidothioic acid, diphenyldiazeneformimidothioic acid, phenyldiazeneacetimidothioic acid, and diphenyldiazeneacetimidothioic acid.

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N Valence Stabilizer #35: Examples of imidoxyldiazenes, bis(imidoxyldiazenes), and poly(imidoxyldiazenes), (N-N Tridentates and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetimidoxyldiazene; benzimidoxyldiazene; and cyclohexylimidoxyldiazene.

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N Valence Stabilizer #36: Examples of diazenediformimidamides (1,2-diazenediamidines), diazenediacetimidamides (1,2-diazene-di-alpha-amidinoalkanes(alkenes)), bis(diazenediformimidamides), bis(diazenediacetimidamides), poly(diazenediformimidamides), and poly(diazenediacetimidamides) (N-N Tridentates and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformimidamide (1,2-diazenediamidine), diazenediacetimidamide (1,2-diazene-di-alpha-amidinomethane); diphenyldiazenediformimidamide; tetraphenyldiazenediformimidamide; diphenyldiazenediacetimidamide; and tetraphenyldiazenediacetimidamide.

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N Valence Stabilizer #37: Examples of diazenediformimidic acid, diazenediacetimidic acid, bis(diazenediformimidic acid), bis(diazenediacetimidic acid), poly(diazenediformimidic acid), and poly(diazenediacetimidic acid), and derivatives thereof (N-N Tridentates and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformimidic acid, diazenediacetimidic acid, diphenyldiazenediformimidic acid, and diphenyldiazenediacetimidic acid.

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N Valence Stabilizer #38: Examples of diazenediformimidothioic acid, diazenediacetimidothioic acid, bis(diazenediformimidothioic acid), bis(diazenediacetimidothioic acid), poly(diazenediformimidothioic acid), and poly(diazenediacetimidothioic acid), and derivatives thereof (N-N Tridentates and N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformimidothioic acid, diazenediacetimidothioic acid, diphenyldiazenediformimidothioic acid, and diphenyldiazenediacetimidothioic acid.

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N Valence Stabilizer #39: Examples of diimidoxyldiazenes, bis(diimidoxyldiazenes), and poly(diimidoxyldiazenes), (N-N Tridentates and N-N Hexadentates) that meet the requirements

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for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diacetimidoyldiazene; dibenzimidoyldiazene; and dicyclohexylimidoyldiazene.

N Valence Stabilizer #40: Examples of ortho-amino (or -hydrazido) substituted formazans, bis(o-amino or -hydrazido substituted formazans), and poly(o-amino or -hydrazido substituted formazans) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 1-(2-aminophenyl)-3,5-diphenylformazan; and 1,5-bis(2-aminophenyl)-3-phenylformazan.

N Valence Stabilizer #41: Examples of ortho-amino (or -hydrazido) substituted azines (including ketazines), bis(o-amino or hydrazido substituted azines), and poly(o-amino or hydrazido substituted azines) (N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-amino-1-benzalazine; 2-amino-1-naphthalazine; and 2-amino-1-cyclohexanonazine.

N Valence Stabilizer #42: Examples of Schiff Bases with one Imine (C=N) Group and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Bidentates, N-N Tridentates, N-N Tetracentates, N-N Pentacentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-(2-Aminobenzaldehyde)isopropylamine; N-(2-Pyridinecarboxaldehyde)isopropylamine; N-(2-Pyrrolecarboxaldehyde)isopropylamine; N-(2-Acetylpyridino)isopropylamine; N-(2-Acetylpyrrolo)isopropylamine; N-(2-Aminoacetophenono)isopropylamine; N-(2-Aminobenzaldehyde)cyclohexylamine; N-(2-Pyridinecarboxaldehyde)cyclohexylamine; N-(2-Pyrrolecarboxaldehyde)cyclohexylamine; N-(2-Acetylpyridino)cyclohexylamine; N-(2-Acetylpyrrolo)cyclohexylamine; N-(2-Aminoacetophenono)cyclohexylamine; N-(2-Aminobenzaldehyde)aniline; N-(2-Pyridinecarboxaldehyde)aniline; N-(2-Pyrrolecarboxaldehyde)aniline; N-(2-Acetylpyridino)aniline; N-(2-Acetylpyrrolo)aniline; N-(2-Aminoacetophenono)aniline; N-(2-Aminobenzaldehyde)aminonorborene; N-(2-Pyridinecarboxaldehyde)aminonorborene; N-(2-

Pyrrolecaboxaldehydo)aminonorbornane; N-(2-Acetylpyridino)aminonorbornane; N-(2-Acetylpyrrolo)aminonorbornane; N-(2-Aminoacetophenono)aminonorbornane; 2-pyrrolecaboxaldehyde phenylhydrazone; 2-pyrrolecaboxaldehyde 2-pyridyl hydrazone; 2-aminobenzaldehyde phenylhydrazone (nitro); and 2-aminobenzaldehyde 2-pyridyl hydrazone.

5 Also includes hydrazones with ortho-N substitution.

- N Valence Stabilizer #43: Examples of Schiff Bases with two Imine (C=N) Groups and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution
- 10 (N-N Bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N’-(Glyoxalo)diisopropylamine; N,N’-(Glyoxalo)dicyclohexylamine; N,N’-(Glyoxalo)dianiline; N,N’-(Glyoxalo)di-aminonorbornane; N,N’-(Malondialdehydo)diisopropylamine; N,N’-(Malondialdehydo)dicyclohexylamine; N,N’-(Malondialdehydo)dianiline; N,N’-(Malondialdehydo)di-aminonorbornane; N,N’-
- 15 (Phthalicdialdehydo)diisopropylamine; N,N’-(Phthalicdialdehydo)dicyclohexylamine; N,N’-(Phthalicdialdehydo)dianiline; N,N’-(Phthalicdialdehydo)di-aminonorbornane; N,N’-(Formylcamphoro)diisopropylamine; N,N’-(Formylcamphoro)dicyclohexylamine; N,N’-(Formylcamphoro)dianiline; N,N’-(Formylcamphoro)di-aminonorbornane; N,N’-(Acetylacetonato)diisopropylamine; N,N’-(Acetylacetonato)dicyclohexylamine; N,N’-
- 20 (Acetylacetonato)dianiline; N,N’-(Acetylacetonato)di-aminonorbornane; N,N’-(Diacetylbenzeno)diisopropylamine; N,N’-(Diacetylbenzeno)dicyclohexylamine; N,N’-(Diacetylbenzeno)dianiline; N,N’-(Diacetylbenzeno)di-aminonorbornane; N,N’-(1,2-Cyclohexanono)diisopropylamine; N,N’-(1,2-Cyclohexanono)dicyclohexylamine; N,N’-(1,2-Cyclohexanono)dianiline; N,N’-(1,2-Cyclohexanono)di-aminonorbornane; N,N’-
- 25 (Camphorquinono)diisopropylamine; N,N’-(Camphorquinono)dicyclohexylamine; N,N’-(Camphorquinono)dianiline; N,N’-(Camphorquinono)di-aminonorbornane; N,N’-(Benzaldehydo)ethylenediamine; N,N’-(Naphthaldehydo)ethylenediamine; N,N’-(Acetophenono)ethylenediamine; ; N,N’-(Benzaldehydo)trimethylenediamine; N,N’-(Naphthaldehydo)trimethylenediamine; N,N’-(Acetophenono)trimethylenediamine; ; N,N’-
- 30 (Benzaldehydo)cyclohexane-1,2-diamine; N,N’-(Naphthaldehydo)cyclohexane-1,2-diamine; N,N’-(Acetophenono)cyclohexane-1,2-diamine; N,N’-(Benzaldehydo)-1,2-diaminobenzene;

N,N'-(Naphthaldehydo)-1,2-diaminobenzene; N,N'-(Acetophenono)-1,2-diaminobenzene; N,N'-(Acetylacetonato)ethylenediamine; N,N'-(Acetylacetonato)-1,2-cyclohexylenediamine; N,N'-(Acetylacetonato)-1,2-propylenediamine; N,N'-(Glyoxalo)-o-phenylenediamine; and N,N'-(Glyoxalo)ethylenediamine. Also includes dihydrazones.

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N Valence Stabilizer #44: Examples of Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Bidentates, N-N Tridentates, N-N Tetracentates, N-N Pentacentates, or N-N Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce⁺⁴ include, but are not

- 10 limited to: N,N'-(2,6-Pyridinedicarboxaldehydo)diisopropylamine; N,N'-(2,6-Pyridinedicarboxaldehydo)dicyclohexylamine; N,N'-(2,6-Pyridinedicarboxaldehydo)dianiline; N,N'-(2,6-Pyridinedicarboxaldehydo)di-aminonorbornane; N,N'-(2,5-Pyrroledicarboxaldehydo)diisopropylamine; N,N'-(2,5-Pyrroledicarboxaldehydo)dicyclohexylamine; N,N'-(2,5-Pyrroledicarboxaldehydo)dianiline;
- 15 N,N'-(2,5-Pyrroledicarboxaldehydo)di-aminonorbornane; N,N'-(o-Aminophthalicdialdehydo)diisopropylamine; N,N'-(o-Aminophthalicdialdehydo)dicyclohexylamine; N,N'-(o-Aminophthalicdialdehydo)dianiline; N,N'-(o-Aminophthalicdialdehydo)di-aminonorbornane; N,N'-(o-Aminoformylcamphoro)diisopropylamine; N,N'-(o-Aminoformylcamphoro)dicyclohexylamine;
- 20 N,N'-(o-Aminoformylcamphoro)dianiline; N,N'-(o-Aminoformylcamphoro)di-aminonorbornane; N,N'-(2,6-Diacetylpyridino)diisopropylamine; N,N'-(2,6-Diacetylpyridino)dicyclohexylamine; N,N'-(2,6-Diacetylpyridino)dianiline; N,N'-(2,6-Diacetylpyridino)di-aminonorbornane; N,N'-(o-Aminodiacetylbenzeno)diisopropylamine; N,N'-(o-Aminodiacetylbenzeno)dicyclohexylamine; N,N'-(o-Aminodiacetylbenzeno)dianiline; N,N'-(o-Aminodiacetylbenzeno)di-aminonorbornane; N,N'-(3,6-Diamino-1,2-
- 25 cyclohexanono)diisopropylamine; N,N'-(3,6-Diamino-1,2-cyclohexanono)dicyclohexylamine; N,N'-(3,6-Diamino-1,2-cyclohexanono)dianiline; N,N'-(3,6-Diamino-1,2-cyclohexanono)di-aminonorbornane; N,N'-(2,5-Diacetylpyrrolo)diisopropylamine; N,N'-(2,5-Diacetylpyrrolo)dicyclohexylamine; N,N'-(2,5-Diacetylpyrrolo)dianiline; N,N'-(2,5-Diacetylpyrrolo)di-aminonorbornane; N,N'-(o-Aminobenzaldehydo)ethylenediamine; N,N'-(o-Aminonaphthaldehydo)ethylenediamine; N,N'-(o-Aminoacetophenono)ethylenediamine; ; N,N'-
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(o-Aminobenzaldehydo)trimethylenediamine; N,N'-(o-Aminonaphthaldehydo)trimethylenediamine; N,N'-(o-Aminoacetophenono)trimethylenediamine; ; N,N'-(o-Aminobenzaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Aminonaphthaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Aminoacetophenono)cyclohexane-1,2-diamine; N,N'-(o-Aminobenzaldehydo)-1,2-diaminobenzene; N,N'-(o-Aminonaphthaldehydo)-1,2-diaminobenzene; and N,N'-(o-Aminoacetophenono)-1,2-diaminobenzene. Also includes hydrazones with ortho-N substitution.

N Valence Stabilizer #45: Examples of Schiff Bases with three Imine (C=N) Groups and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution (N-N Tridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N',N''-(Benzaldehydo)tris(2-aminoethyl)amine; N,N',N''-(Naphthaldehydo)tris(2-aminoethyl)amine; and N,N',N''-(Acetophenono)tris(2-aminoethyl)amine. Also includes trihydrazones.

N Valence Stabilizer #46: Examples of Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-amino or imino or oximo or diazeno or hydrazido substitution (N-N Tridentates, N-N Tetridentates, N-N Pentadentates, or N-N Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N',N''-(o-Aminobenzaldehydo)tris(2-aminoethyl)amine; N,N',N''-(o-Aminonaphthaldehydo)tris(2-aminoethyl)amine; and N,N',N''-(o-Aminoacetophenono)tris(2-aminoethyl)amine.

S Valence Stabilizer #1: Examples of macrocyclic, macrobicyclic, and macropolycyclic oligothioketones (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of thioketones (especially in the beta position) (S-S Bidentates, S-S Tetridentates, and S-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hexathioketocyclotetracosane ([24]ane(=S)₆); hexathioketocycloheicosane ([21]ane(=S)₆); hexathioketocyclooctadecane ([18]ane(=S)₆); hexathioketocyclopentadecane ([15]ane(=S)₆); tetrathioketocycloeicosane ([20]ane(=S)₄);

tetrathioketocyclooctadecane ([18]ane(=S)₄); tetrathioketocyclohexadecane ([16]ane(=S)₄);
tetrathioketocyclotetradecane ([14]ane(=S)₄); tetrathioketocyclododecane ([12]ane(=S)₄);
dithioketocyclohexadecane ([16]ane(=S)₂); dithioketocyclotetraadecane ([14]ane(=S)₂);
dithioketocyclododecane ([12]ane(=S)₂); dithioketocyclodecane ([10]ane(=S)₂); and
5 dithioketocyclooctane ([8]ane(=S)₂).

S Valence Stabilizer #2: Examples of macrocyclic, macrobicyclic, and macropolycyclic
dithiolenes (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding
sites are composed of alpha-, alpha-dithiolenes (meaning two thiol groups on a single carbon
10 atom in the ring) (S-S Bidentates, S-S Tetridentates, and S-S Hexadentates) that meet the
requirements for use as “wide band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
hexathiolocyclotetracosane ([24]ane(-SH)₆); hexathiolocycloheicosane ([21]ane(-SH)₆);
hexathiolocyclooctadecane ([18]ane(-SH)₆); hexathiolocyclopentadecane ([15]ane(-SH)₆);
tetrathiolocycloeicosane ([20]ane(-SH)₄); tetrathiolocyclooctadecane ([18]ane(-SH)₄);
15 tetrathiolocyclohexadecane ([16]ane(-SH)₄); tetrathiolocyclotetradecane ([14]ane(-SH)₄);
tetrathiolocyclododecane ([12]ane(-SH)₄); dithiolocyclohexadecane ([16]ane(-SH)₂);
dithiolocyclotetraadecane ([14]ane(-SH)₂); dithiolocyclododecane ([12]ane(-SH)₂);
dithiolocyclodecane ([10]ane(-SH)₂); and dithiolocyclooctane ([8]ane(-SH)₂).

20 S Valence Stabilizer #3: Examples of dithioimidodialdehydes, dithiohydrazidodialdehydes
(thioacyl thiohydrazides), bis(dithioimidodialdehydes), bis(dithiohydrazidodialdehydes),
poly(dithioimidodialdehydes), and poly(dithiohydrazidodialdehydes) (S-S Bidentates, S-S
Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence
stabilizers for Ce⁺⁴ include, but are not limited to: dithiodiacetamide, dithiodipropanamide,
25 dithiodibutanamide, dithiodibenzamide, and dithiodicyclohexamide.

S Valence Stabilizer #4: Examples of dithioimidodicarbonic acids, dithiohydrazidodicarbonic
acids, bis(dithioimidodicarbonic acids), bis(dithiohydrazidodicarbonic acids),
poly(dithioimidodicarbonic acids), poly(dithiohydrazidodicarbonic acids) and derivatives thereof
30 (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide
band” valence stabilizers for Ce⁺⁴ include, but are not limited to: dithioimidodicarbonic acid,

dithiohydrazidodicarbonic acid, O-phenyldithioimidodicarbonic acid, O-benzoyldithioimidodicarbonic acid, O-cyclohexyldithioimidodicarbonic acid, O-norbornyldithioimidodicarbonic acid, O,O'-diphenyldithioimidodicarbonic acid, O,O'-dibenzoyldithioimidodicarbonic acid, O,O'-dicyclohexyldithioimidodicarbonic acid, and O,O'-norbornyldithioimidodicarbonic acid.

S Valence Stabilizer #5: Examples of 1,3-dithioketones (dithio-beta-ketonates), 1,3,5-trithioketones, bis(1,3-dithioketones), and poly(1,3-dithioketones) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hexafluoropentanedithione; 1,3-diphenyl-1,3-propanedithione; thiobenzoylthiopinacolone; dithiocyclohexoxymethane; diphenylpentanetrithionate; tetramethylnonanetrithionate; hexafluoroheptanetrithionate; trifluoroheptanetrithionate; 1-(2-thienyl)-1,3-butanedithione, 1-(2-naphthyl)-1,3-butanedithione, trifluorothioacetylthiocamphor; and 1,3-indandithione.

S Valence Stabilizer #6: Examples of 1,2-dithioketones (dithiolenes, dithio-alpha-ketonates), 1,2,3-trithioketones, dithiotropolonates, o-dithioquinones, bis(1,2-dithioketones), and poly(1,2-dithioketones) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

dithiotropolone; 1,2-dithiobenzoquinone (o-dithioquinone)(o-benzenedithiolate)(bdt); di-tert-butyl-1,2-dithiobenzoquinone; hexafluoro-1,2-dithiobenzoquinone; 1,2-dithionaphthoquinone; 9,10-dithiophenanthroquinone; ethylenedithiolene (edt); maleonitriledithiolene (mnt); trifluoromethyldithiolene (tfd); carbomethoxydithiolene (cmt); trithionedithiolene (dmit); toluenedithiolate (tdt); dithiomanaldehyde (propenethionethiolate)(ptt); dithioacetylacetate (SacSac); dijulolidinedithiolene; 2,3-piperazinedithiolate; di(4-aminophenyl)dithiolene; dimercaptoisotrithione (dmit); (4-octylphenyl)dithiolene; benzenetetrathiol; tetrathiosquaric acid; trithiodeltic acid; pentathioacroconic acid; dithioacroconic acid; hexathiorhodizonic acid; dithiorhodizonic acid; ethylenetetrathiol; trans-butadienetetrathiolate; tetrathiooxalic acid; 1,2-indandithione; naphthothioquinone; acenaphthenethioquinone; aceanthrenethioquinone; and indole-2,3-dithione (thioisatin).

S Valence Stabilizer #7: Examples of dithiomalonamides (dithiomalonodiamides), bis(dithiomalonamides), and polydithiomalonamides (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiomalonamide, N-phenyldithiomalonamide, N-

- 5 benzyldithiomalonamide, N-pentafluorophenyldithiomalonamide, N-cyclohexyldithiomalonamide, N-norbornyldithiomalonamide, N,N'-diphenyldithiomalonamide, N,N'-dibenzoyldithiomalonamide, N,N'-dipentafluorophenyldithiomalonamide, N,N'-dicyclohexyldithiomalonamide, and N,N'-norbornyldithiomalonamide.
- 10 S Valence Stabilizer #8: Examples of 2-thioacylthioacetamides, bis(2-thioacylthioacetamides), and poly(2-thioacylthioacetamides) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-thioacetothioacetamide, N-phenyl-2-thioacetothioacetamide, N-pentafluorophenyl-2-thioacetothioacetamide, N-benzyl-2-thioacetothioacetamide, N-cyclohexyl-2-
- 15 thioacetothioacetamide, N-norbornyl-2-thioacetothioacetamide, N-phenyl-2-thiobenzothioacetamide, N-pentafluorophenyl-2-pentafluorothiobenzothioacetamide, and N-cyclohexyl-2-thiocyclohexothioacetamide.

S Valence Stabilizer #9: Examples of dithioacyl sulfides, bis(dithioacyl sulfides), and

- 20 poly(dithioacyl sulfides), (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioacetyl sulfide; dithiopropionyl sulfide; dithiobenzoyl sulfide; and dithiopentafluorobenzoyl sulfide.

- 25 S Valence Stabilizer #10: Examples of trithiodicarbonyl diamides, bis(trithiodicarbonyl diamides), and poly(trithiodicarbonyl diamides) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: trithiodicarbonyl diamide; N-phenyltrithiodicarbonyl diamide; N-pentafluorophenyltrithiodicarbonyl diamide; N-benzyltrithiodicarbonyl diamide; N-
- 30 cyclohexyltrithiodicarbonyl diamide; N-norbornyltrithiodicarbonyl diamide; N,N'-diphenyltrithiodicarbonyl diamide; N,N'-dipentafluorophenyltrithiodicarbonyl diamide; N,N'-

dibenzyltrithiodicarbonic diamide; N,N'-dicyclohexyltrithiodicarbonic diamide; and N,N'-dinorbornyltrithiodicarbonic diamide.

S Valence Stabilizer #11: Examples of pentathio-, tetrathio-, or trithiodicarbonic acids,

- 5 bis(pentathio-, tetrathio-, or trithiodicarbonic acids), poly(pentathio-, tetrathio-, or trithiodicarbonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: pentathiodicarbonic acid, tetrathiodicarbonic acid, trithiodicarbonic acid, O-phenyltrithiodicarbonic acid, O-benzyltrithiodicarbonic acid, O-cyclohexyltrithiodicarbonic acid, O-norbornyltrithiodicarbonic acid, O,O'-diphenyltrithiodicarbonic acid, O,O'-dibenzyltrithiodicarbonic acid, O,O'-dicyclohexyltrithiodicarbonic acid, and O,O'-dinorbornyltrithiodicarbonic acid.
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S Valence Stabilizer #12: Examples of dithiohypophosphoric acids, bis(dithiohypophosphoric

- 15 acids), poly(dithiohypophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiohypophosphoric acid, methyl dithiohypophosphoric acid, isopropyl dithiohypophosphoric acid, tert-butyl dithiohypophosphoric acid, phenyl dithiohypophosphoric acid, pentafluorophenyl dithiohypophosphoric acid, benzyl dithiohypophosphoric acid, cyclohexyl dithiohypophosphoric acid, norbornyl dithiohypophosphoric acid, dimethyl dithiohypophosphoric acid, diisopropyl dithiohypophosphoric acid, di-tert-butyl dithiohypophosphoric acid, diphenyl dithiohypophosphoric acid, di-pentafluorophenyl dithiohypophosphoric acid, dibenzyl dithiohypophosphoric acid, dicyclohexyl dithiohypophosphoric acid, and dinorbornyl dithiohypophosphoric acid.
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S Valence Stabilizer #13: Examples of dithiohypophosphoramides,

- bis(dithiohypophosphoramides), and poly(dithiohypophosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiohypophosphoramide, N-methyl dithiohypophosphoramide, N-isopropyl dithiohypophosphoramide, N-tert-
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butyldithiohypophosphoramide, N-phenyldithiohypophosphoramide, N-pentafluorophenyldithiohypophosphoramide, N-benzoyldithiohypophosphoramide, N-cyclohexyldithiohypophosphoramide, N-norbornyldithiohypophosphoramide, N,N''-dimethyldithiohypophosphoramide, N,N''-diisopropyldithiohypophosphoramide, N,N''-di-tert-butyldithiohypophosphoramide, N,N''-diphenyldithiohypophosphoramide, N,N''-di-pentafluorophenyldithiohypophosphoramide, N,N''-dibenzoyldithiohypophosphoramide, N,N''-dicyclohexyldithiohypophosphoramide, and N,N''-dinorbornyldithiohypophosphoramide.

S Valence Stabilizer #14: Examples of dithioimidodiphosphoric acids,

- 10 dithiohydrazidodiphosphoric acids, bis(dithioimidodiphosphoric acids), bis(dithiohydrazidodiphosphoric acids), poly(dithioimidodiphosphoric acids), poly(dithiohydrazidodiphosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioimidodiphosphoric acid,
- 15 methyldithioimidodiphosphoric acid, isopropyldithioimidodiphosphoric acid, tert-butyldithioimidodiphosphoric acid, phenyldithioimidodiphosphoric acid, pentafluorophenyldithioimidodiphosphoric acid, benzoyldithioimidodiphosphoric acid, cyclohexyldithioimidodiphosphoric acid, norbornyldithioimidodiphosphoric acid, dimethyldithioimidodiphosphoric acid, diisopropyldithioimidodiphosphoric acid, di-tert-
- 20 butyldithioimidodiphosphoric acid, diphenyldithioimidodiphosphoric acid, di-pentafluorophenyldithioimidodiphosphoric acid, dibenzoyldithioimidodiphosphoric acid, dicyclohexyldithioimidodiphosphoric acid, and dinorbornyldithioimidodiphosphoric acid.

S Valence Stabilizer #15: Examples of dithioimidodiphosphoramides,

- 25 dithiohydrazidodiphosphoramides, bis(dithioimidodiphosphoramides), bis(dithiohydrazidodiphosphoramides), poly(dithioimidodiphosphoramides), and poly(dithiohydrazidodiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioimidodiphosphoramide, N-methyldithioimidodiphosphoramide, N-
- 30 isopropyldithioimidodiphosphoramide, N-tert-butyldithioimidodiphosphoramide, N-phenyldithioimidodiphosphoramide, N-pentafluorophenyldithioimidodiphosphoramide, N-

benzyldithioimidodiphosphoramide, N-cyclohexyldithioimidodiphosphoramide, N-norbornyldithioimidodiphosphoramide, N,N'''-dimethyldithioimidodiphosphoramide, N,N'''-diisopropyldithioimidodiphosphoramide, N,N'''-di-tert-butyldithioimidodiphosphoramide, N,N'''-diphenyldithioimidodiphosphoramide, N,N'''-di-
5 pentafluorophenyldithioimidodiphosphoramide, N,N'''-dibenzoyldithioimidodiphosphoramide, N,N'''-dicyclohexyldithioimidodiphosphoramide, and N,N'''-dinorbornyldithioimidodiphosphoramide.

S Valence Stabilizer #16: Examples of dithiodiphosphoramides, bis(dithiodiphosphoramides),
10 and poly(dithiodiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodiphosphoramide, N-methyldithiodiphosphoramide, N-isopropyldithiodiphosphoramide, N-tert-butyldithiodiphosphoramide, N-phenyldithiodiphosphoramide, N-pentafluorophenyldithiodiphosphoramide, N-
15 benzyldithiodiphosphoramide, N-cyclohexyldithiodiphosphoramide, N-norbornyldithiodiphosphoramide, N,N'''-dimethyldithiodiphosphoramide, N,N'''-diisopropyldithiodiphosphoramide, N,N'''-di-tert-butyldithiodiphosphoramide, N,N'''-diphenyldithiodiphosphoramide, N,N'''-di-pentafluorophenyldithiodiphosphoramide, N,N'''-dibenzoyldithiodiphosphoramide, N,N'''-dicyclohexyldithiodiphosphoramide, and N,N'''-
20 dinorbornyldithiodiphosphoramide.

S Valence Stabilizer #17: Examples of dithiodiphosphoric acids, bis(dithiodiphosphoric acids), poly(dithiodiphosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}
25 include, but are not limited to: dithiodiphosphoric acid, methyldithiodiphosphoric acid, isopropyldithiodiphosphoric acid, tert-butyldithiodiphosphoric acid, phenyldithiodiphosphoric acid, pentafluorophenyldithiodiphosphoric acid, benzyldithiodiphosphoric acid, cyclohexyldithiodiphosphoric acid, norbornyldithiodiphosphoric acid, dimethyldithiodiphosphoric acid, diisopropyldithiodiphosphoric acid, di-tert-
30 butyldithiodiphosphoric acid, diphenyldithiodiphosphoric acid, di-

pentafluorophenyldithiodiphosphoric acid, dibenzylthiodiphosphoric acid, dicyclohexyldithiodiphosphoric acid, and dinorbornyldithiodiphosphoric acid.

S Valence Stabilizer #18: Examples of trithiophosphoric acids (phosphorotrithioic acids),

- 5 bis(trithiophosphoric acids), poly(trithiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: trithiophosphoric acid, O-phenyltrithiophosphoric acid, O-benzyltrithiophosphoric acid, O-cyclohexyltrithiophosphoric acid, O-norbornyltrithiophosphoric acid, O,S-diphenyltrithiophosphoric acid, O,S-
- 10 dibenzyltrithiophosphoric acid, O,S-dicyclohexyltrithiophosphoric acid, and O,S-dinorbornyltrithiophosphoric acid.

S Valence Stabilizer #19: Examples of dithiophosphoric acids (phosphorodithioic acids),

- 15 bis(dithiophosphoric acids), poly(dithiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiophosphoric acid, O-phenyldithiophosphoric acid, O-benzylthiodiphosphoric acid, O-cyclohexyldithiophosphoric acid, O-norbornyldithiophosphoric acid, O,O-diphenyldithiophosphoric acid, O,O-
- 20 dibenzylthiodiphosphoric acid, O,O-dicyclohexyldithiophosphoric acid, and O,O-dinorbornyldithiophosphoric acid.

S Valence Stabilizer #20: Examples of tetrathiophosphoric acids (phosphorotetrathioic acids),

- bis(tetrathiophosphoric acids), poly(tetrathiophosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide
- 25 band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrathiophosphoric acid, S-phenyltetrathiophosphoric acid, S-benzyltetrathiophosphoric acid, S-cyclohexyltetrathiophosphoric acid, S-norbornyltetrathiophosphoric acid, S,S-
- diphenyltetrathiophosphoric acid, S,S-dibenzyltetrathiophosphoric acid, S,S-
- dicyclohexyltetrathiophosphoric acid, and S,S-dinorbornyltetrathiophosphoric acid.

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S Valence Stabilizer #21: Examples of phosphoro(dithioperoxo)dithioic acids,

bis[phosphoro(dithioperoxo)dithioic acids], poly[phosphoro(dithioperoxo)dithioic acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 5 phosphoro(dithioperoxo)dithioic acid, O-phenylphosphoro(dithioperoxo)dithioic acid, O-benzylphosphoro(dithioperoxo)dithioic acid, O-cyclohexylphosphoro(dithioperoxo)dithioic acid, O-norbornylphosphoro(dithioperoxo)dithioic acid, O,S-diphenylphosphoro(dithioperoxo)dithioic acid, O,S-dibenzylphosphoro(dithioperoxo)dithioic acid, O,S-dicyclohexylphosphoro(dithioperoxo)dithioic acid, and O,S-dinorbornylphosphoro(dithioperoxo)dithioic acid.
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S Valence Stabilizer #22: Examples of phosphoro(dithioperoxo)thioic acids,

bis[phosphoro(dithioperoxo)thioic acids], poly[phosphoro(dithioperoxo)thioic acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the

- 15 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoro(dithioperoxo)thioic acid, O-phenylphosphoro(dithioperoxo)thioic acid, O-benzylphosphoro(dithioperoxo)thioic acid, O-cyclohexylphosphoro(dithioperoxo)thioic acid, O-norbornylphosphoro(dithioperoxo)thioic acid, O,S-diphenylphosphoro(dithioperoxo)thioic acid, O,S-dibenzylphosphoro(dithioperoxo)thioic acid, O,S-dicyclohexylphosphoro(dithioperoxo)thioic acid, and O,S-dinorbornylphosphoro(dithioperoxo)thioic acid.
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S Valence Stabilizer #23: Examples of phosphoro(dithioperoxo)trithioic acids,

bis[phosphoro(dithioperoxo)trithioic acids], poly[phosphoro(dithioperoxo)trithioic acids], and

- 25 derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoro(dithioperoxo)trithioic acid, O-phenylphosphoro(dithioperoxo)trithioic acid, O-benzylphosphoro(dithioperoxo)trithioic acid, O-cyclohexylphosphoro(dithioperoxo)trithioic acid, O-norbornylphosphoro(dithioperoxo)trithioic acid, O,S-diphenylphosphoro(dithioperoxo)trithioic acid, O,S-dibenzylphosphoro(dithioperoxo)trithioic acid, and O,S-dicyclohexylphosphoro(dithioperoxo)trithioic acid.
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acid, O,S-dicyclohexylphosphoro(dithioperoxo)trithioic acid, and O,S-dinorbornylphosphoro(dithioperoxo)trithioic acid.

S Valence Stabilizer #24: Examples of beta-mercaptothioketones, beta-mercaptothioaldehydes,

5 bis(beta-mercaptothioketones), bis(beta-mercaptothioaldehydes), poly(beta-mercaptothioketones), and poly(beta-mercaptothioaldehydes) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-mercaptopentan-2-thione; 1,3-diphenyl-3-mercaptopropanethioaldehyde; 1,3-dibenzyl-3-mercaptopropanethioaldehyde; 1,3-dicyclohexyl-10 3-mercaptopropanethioaldehyde; 1,3-dinorbornyl-3-mercaptopropanethioaldehyde; 1,3-di(2-thienyl)-3-mercaptopropanethioaldehyde; 1,3-di(2-furyl)-3-mercaptopropanethioaldehyde; o-mercaptothioacetophenone; 5-mercapto-1,4-dithionaphthoquinone; 1-mercaptothioacridone; 1-mercaptodithioanthraquinone; 1,8-dimercaptodithioanthraquinone; and beta-mercaptothiobenzophenone.

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S Valence Stabilizer #25: Examples of N-(aminomethylthiol)thioureas [N-

(aminomercaptomethyl)thioureas], bis[N-(aminomethylthiol)thioureas], and poly[N-(aminomethylthiol)thioureas] (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 20 N’-(aminomercaptomethyl)thiourea; N,N”-dimethyl-N’-(aminomercaptomethyl)thiourea; N,N’-diethyl-N’-(aminomercaptomethyl)thiourea; N,N”-isopropyl-N’-(aminomercaptomethyl)thiourea; N,N”-diphenyl-N’-(aminomercaptomethyl)thiourea; N,N”-dibenzyl-N’-(aminomercaptomethyl)thiourea; N,N”-dicyclohexyl-N’-(aminomercaptomethyl)thiourea; and N,N”-dinorbornyl-N’-(aminomercaptomethyl)thiourea.

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S Valence Stabilizer #26: Examples of dithiooxamides, bis(dithiooxamides), and

poly(dithiooxamides) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiooxamide (rubeanic acid), N-methyldithiooxamide; N-ethyldithiooxamide; N-30 isopropyldithiooxamide; N-phenyldithiooxamide; N-benzoyldithiooxamide; N-cyclohexyldithiooxamide; N-norbornyldithiooxamide; N,N’-dimethyldithiooxamide; N,N’-

diethyldithiooxamide; N,N'-diisopropyldithiooxamide; N,N'-dipenyldithiooxamide; N,N'-dibenzoyldithiooxamide; N,N'-dicyclohexyldithiooxamide; and N,N'-dinorbornyldithiooxamide.

S Valence Stabilizer #27: Examples of 1,1-dithiolates, bis(1,1-dithiolates), and poly(1,1-

- 5 dithiolates) (S-S Bidentates and S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,1-dicyano-2,2-ethylene dithiolate (i-mnt); 1,1-dicarboalkoxy-2,2-ethylene dithiolate (DED); 1,1-di(trifluoromethyl)-2,2-ethylene dithiolate; 1,1-di(pentafluorophenyl)-2,2-ethylene dithiolate; 1-pentamethylene-2,2-ethylene dithiolate; and 1-nitroethylene dithiolate.

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S Valence Stabilizer #28: Examples of dithiomonocarboxylic acids, tri- and tetrathiodicarboxylic Acids, bis(dithiomonocarboxylic acids), bis(tri- and tetrathiodicarboxylic acids), poly(dithiomonocarboxylic acids), poly(tri- and tetrathiodicarboxylic acids), and derivatives thereof (S-S Bidentates and S-S Tetracentates) that meet the requirements for use as “wide band”

- 15 valence stabilizers for Ce^{+4} include, but are not limited to: dithioacetic acid; dithiopropionic acid; dithiobenzoic acid (dtb); dithiophenylacetic acid (dtpa); dithiocyclohexanoic acid; dithiofuroic acid; dithionaphthoic acid; phenyl dithioacetate; phenyl dithiopropionate; phenyl dithiobenzoate; phenyl dithiocyclohexanoate; phenyl dithiofuroate; phenyl dithionaphthoate; tetrathiooxalic acid; tetrathiomalonic acid; tetrathiosuccinic acid; trithiooxalic acid; trithiomalonic acid;
- 20 trithiosuccinic acid; diphenyl tetrathiooxalate; diphenyl tetrathiomalonate; diphenyl tetrathiosuccinate; diphenyl trithiooxalate; diphenyl trithiomalonate; diphenyl trithiosuccinate; pyridine dithiocarboxylic acid; pyrrole dithiocarboxylic acid; thiophene dithiocarboxylic acid; dithionaphthoic acid; and tetrathiocamphonic acid.

- 25 S Valence Stabilizer #29: Examples of perthiomonocarboxylic acids, perthiodicarboxylic acids, bis(perthiomonocarboxylic acids), bis(perthiodicarboxylic acids), poly(perthiomonocarboxylic acids), poly(perthiodicarboxylic acids), and derivatives thereof (S-S Bidentates and S-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: perthioacetic acid; perthiopropionic acid; perthiobenzoic acid;
- 30 perthiophenylacetic acid; perthiocyclohexanoic acid; perthiofuroic acid; perthionaphthoic acid; phenyl perthioacetate; phenyl perthiopropionate; phenyl perthiobenzoate; phenyl

perthiocyclohexanoate; phenyl perthiofuroate; phenyl perthionaphthoate; perthiooxalic acid; perthiomalonic acid; perthiosuccinic acid; diphenyl perthiooxalate; diphenyl perthiomalonate; diphenyl perthiosuccinate; dithiole-3-thione (dithione-3-thione); and benzodithiole-3-thione (benzodithione-3-thione).

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S Valence Stabilizer #30: Examples of dithiocarbonates, trithiocarbonates, perthiocarbonates, bis(dithiocarbonates), bis(trithiocarbonates), and bis(perthiocarbonates) (S-S Bidentates and S-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: S,S-diethyldithiocarbonate; S,S-diisopropyldithiocarbonate; S,S-diphenyldithiocarbonate; S,S-dibenzoyldithiocarbonate; S,S-dicyclohexyldithiocarbonate; S,S-dinorbornyldithiocarbonate; diethyltrithiocarbonate; diisopropyltrithiocarbonate; diphenyltrithiocarbonate; dibenzyltrithiocarbonate; dicyclohexyltrithiocarbonate; and dinorbornyltrithiocarbonate.

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15 S Valence Stabilizer #31: Examples of dithiocarbamates, bis(dithiocarbamates), and poly(dithiocarbamates) (including N-hydroxydithiocarbamates and N-mercaptodithiocarbamates) (S-S Bidentates, S-S Tridentates, and S-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dimethyldithiocarbamate (dmdtc); di(trifluorodimethyl)dithiocarbamate; diethyldithiocarbamate (dedtc);
20 dipropyldithiocarbamate; diisopropyldithiocarbamate; dibutyldithiocarbamate; ditertbutyldithiocarbamate; dicyanamidodithiocarbamate; azidothioformates; diphenyldithiocarbamate; di(pentafluorophenyl)dithiocarbamate; dibenzoyldithiocarbamate; dinaphthyldithiocarbamate; dicyclohexyldithiocarbamate; dinorbornyldithiocarbamate; diadamantyldithiocarbamate; pyrrolidinodithiocarbamate (pyrdtc); piperidinodithiocarbamate
25 (pipdte); morpholinodithiocarbamate (mordtc); thiamorpholinodithiocarbamate; 3-pyrrolinodithiocarbamate; pyrrolodithiocarbamate; oxazolodithiocarbamate; isoxazolodithiocarbamate; thiazolodithiocarbamate; isothiazolodithiocarbamate; indolodithiocarbamate; carbazolodithiocarbamate; pyrazolinodithiocarbamate; imidazolinodithiocarbamate; pyrazolodithiocarbamate; imidazolodithiocarbamate;
30 indazolodithiocarbamate; and triazolodithiocarbamate.

S Valence Stabilizer #32: Examples of dithiocarbazates (dithiocarbazides), bis(dithiocarbazates), and poly(dithiocarbazates) (S-S Bidentates, S-S Tridentates, and S-S Tetracentates; or possibly N-S Bidentates, N-S Tridentates, and N-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N’-

- 5 dimethyldithiocarbazate; N,N’-di(trifluoromethyl)dithiocarbazate; N,N’-diethyldithiocarbazate; N,N’-diphenyldithiocarbazate; N,N’-dibenzoyldithiocarbazate; N,N’-di(pentafluorophenyl)dithiocarbazate; N,N’-dicyclohexyldithiocarbazate; and N,N’-dinorbornyldithiocarbazate.

- 10 S Valence Stabilizer #33: Examples of thiocyanate ligands (S monodentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: thiocyanate (-SCN).

- O Valence Stabilizer #1: Examples of biurets (imidodicarbonic diamides), isobiurets, biureas, triurets, triureas, bis(biurets), bis(isobiurets), bis(biureas), poly(biurets), poly(isobiurets), and poly(biureas) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: biuret, isobiuret, biurea, triuret, triurea, nitrobiuret, dinitrobiuret, aminobiuret, diamminobiuret, oxybiuret, dioxybiuret, cyanobiuret, methylbiuret, ethylbiuret, isopropylbiuret, phenylbiuret, benzylbiuret, cyclohexylbiuret, norbornylbiuret, adamantylbiuret, dimethylbiuret, diethylbiuret, diisopropylbiuret, diphenylbiuret, dibenzoylbiuret, dicyclohexylbiuret, dinorbornylbiuret, and diadamantylbiuret.

- O Valence Stabilizer #2: Examples of acylureas, aroylureas, bis(acylureas), bis(aroylureas), poly(acylureas), and poly(aroylureas) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: formylurea, acetylurea, benzoylurea, cyclohexoylurea, pentafluorobenzoylurea, N-methylacetylurea, N-phenylbenzoylurea, and N-cyclohexylcyclohexoylurea.

- 30 O Valence Stabilizer #3: Examples of imidodialdehydes, hydrazidodialdehydes (acylhydrazides), bis(imidodialdehydes), bis(hydrazidodialdehydes), poly(imidodialdehydes), and

poly(hydrazidodialdehydes) (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diacetamide, dipropanamide, dibutanamide, dibenzamide, and dicyclohexamide.

- 5 O Valence Stabilizer #4: Examples of imidodicarbonic acids, hydrazidodicarbonic acids, bis(imidodicarbonic acids), bis(hydrazidodicarbonic acids), poly(imidodicarbonic acids), poly(hydrazidodicarbonic acids) and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: imidodicarbonic acid, hydrazidodicarbonic acid, O-phenylimidodicarbonic acid, O-benzylimidodicarbonic acid, O-cyclohexylimidodicarbonic acid, O-norbornylimidodicarbonic acid, O,O'-diphenylimidodicarbonic acid, O,O'-dibenzylimidodicarbonic acid, O,O'-dicyclohexylimidodicarbonic acid, and O,O'-dinorbornylimidodicarbonic acid.
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- 15 O Valence Stabilizer #5: Examples of imidodisulfamic acid, imidodisulfuric acid, bis(imidodisulfamic acid), bis(imidodisulfuric acid), poly(imidodisulfamic acid), and poly(imidodisulfuric acid) and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: imidodisulfamic acid, imidodisulfuric acid, N-phenylimidodisulfamic acid, N-benzylimidodisulfamic acid, N-cyclohexylimidodisulfamic acid, N-norbornylimidodisulfamic acid, N,N'-diphenylimidodisulfamic acid, N,N'-dibenzylimidodisulfamic acid, N,N'-dicyclohexylimidodisulfamic acid, and N,N'-norbornylimidodisulfamic acid.
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- 25 O Valence Stabilizer #6: Examples of 1,3-diketones (beta-diketonates), 1,3,5-triketones, bis(1,3-diketones), and poly(1,3-diketones), all with a molecular weight greater than 125 (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hexafluoropentanedione; dibenzoylmethane (1,3-diphenyl-1,3-propanedione); benzoylpinacolone; dicyclohexoylmethane; diphenylpentanetrionate; dibenzoylacetone; benzoylacetylacetone; dibenzoylacetylacetone;
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tetramethylnonanetrionate; hexafluoroheptanetrionate; trifluoroheptanetrionate; trifluoroacetylcamphor (facam); and 1,3-indandione.

- 5 O Valence Stabilizer #7: Examples of 1,2-diketones (alpha-diketonates), 1,2,3-triketones, tropolonates, o-quinones, bis(1,2-diketones), and poly(1,2-diketones), all with a molecular weight greater than 100 (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: tropolone; 1,2-benzoquinone (o-quinone); di-tert-butyl-1,2-benzoquinone; hexafluoro-1,2-
10 benzoquinone; 1,2-naphthoquinone; 9,10-phenanthroquinone; and 1,2-indandione.

- O Valence Stabilizer #8: Examples of malonamides (malonodiamides), bis(malonamides), and polymalonamides (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the
15 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: malonamide, N-phenylmalonamide, N-benzylmalonamide, N-pentafluorophenylmalonamide, N-cyclohexylmalonamide, N-norbornylmalonamide, N,N'-diphenylmalonamide, N,N'-dibenzylmalonamide, N,N'-dipentafluorophenylmalonamide, N,N'-dicyclohexylmalonamide, and N,N'-norbornylmalonamide.

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- O Valence Stabilizer #9: Examples of 2-acylacetamides, bis(2-acylacetamides), and poly(2-acylacetamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-acetoacetamide, N-phenyl-2-acetoacetamide, N-pentafluorophenyl-2-acetoacetamide, N-
25 benzyl-2-acetoacetamide, N-cyclohexyl-2-acetoacetamide, N-norbornyl-2-acetoacetamide, N-phenyl-2-benzoacetamide, N-pentafluorophenyl-2-pentafluorobenzoacetamide, and N-cyclohexyl-2-cyclohexoacetamide.

- O Valence Stabilizer #10: Examples of monothiodicarbonic diamides, bis(monothiodicarbonic
30 diamides), and poly(monothiodicarbonic diamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

include, but are not limited to: monothiodicarbonic diamide; N-phenylmonothiodicarbonic diamide; N-pentafluorophenylmonothiodicarbonic diamide; N-benzylmonothiodicarbonic diamide; N-cyclohexylmonothiodicarbonic diamide; N-norbornylmonothiodicarbonic diamide; N,N'-diphenylmonothiodicarbonic diamide; N,N'-dipentafluorophenylmonothiodicarbonic
5 diamide; N,N'-dibenzylmonothiodicarbonic diamide; N,N'-dicyclohexylmonothiodicarbonic diamide; and N,N'-dinorbornylmonothiodicarbonic diamide.

O Valence Stabilizer #11: Examples of monothiodicarbonic acids, bis(monothiodicarbonic acids), poly(monothiodicarbonic acids), and derivatives thereof (O-O Bidentates, O-O
10 Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiodicarbonic acid, O-phenylmonothiodicarbonic acid, O-benzylmonothiodicarbonic acid, O-cyclohexylmonothiodicarbonic acid, O-norbornylmonothiodicarbonic acid, O,O'-diphenylmonothiodicarbonic acid, O,O'-dibenzylmonothiodicarbonic acid, O,O'-
15 dicyclohexylmonothiodicarbonic acid, and O,O'-dinorbornylmonothiodicarbonic acid.

O Valence Stabilizer #12: Examples of trithionic acid, bis(trithionic acid), poly(trithionic acid), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
20 diphenyl trithionate, dipentafluorodiphenyl trithionate, dicyclohexyl trithionate, and dinorbornyl trithionate.

O Valence Stabilizer #13: Examples of hypophosphoric acids, bis(hypophosphoric acids), and poly(hypophosphoric acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O
25 Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hypophosphoric acid, O-methylhypophosphoric acid, O-isopropylhypophosphoric acid, O-tert-butylhypophosphoric acid, O-phenylhypophosphoric acid, O-pentafluorophenylhypophosphoric acid, O-benzylhypophosphoric acid, O-cyclohexylhypophosphoric acid, O-norbornylhypophosphoric acid, O,O'-
30 dimethylhypophosphoric acid, O,O'-diisopropylhypophosphoric acid, O,O'-di-tert-butylhypophosphoric acid, O,O'-diphenylhypophosphoric acid, O,O'-di-

pentafluorophenylhypophosphoric acid, O,O''-dibenzylhypophosphoric acid, O,O''-dicyclohexylhypophosphoric acid, and O,O''-dinorbornylhypophosphoric acid.

O Valence Stabilizer #14: Examples of hypophosphoramides, bis(hypophosphoramides), and

- 5 poly(hypophosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hypophosphoramide, N-methylhypophosphoramide, N-isopropylhypophosphoramide, N-tert-butylhypophosphoramide, N-phenylhypophosphoramide, N-pentafluorophenylhypophosphoramide, N-benzylhypophosphoramide, N-cyclohexylhypophosphoramide, N-norbornylhypophosphoramide, N,N'''-dimethylhypophosphoramide, N,N'''-diisopropylhypophosphoramide, N,N'''-di-tert-butylhypophosphoramide, N,N'''-diphenylhypophosphoramide, N,N'''-dipentafluorophenylhypophosphoramide, N,N'''-dibenzylhypophosphoramide, N,N'''-dicyclohexylhypophosphoramide, and N,N'''-dinorbornylhypophosphoramide.

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O Valence Stabilizer #15: Examples of imidodiphosphoric acids, hydrazidodiphosphoric acids, bis(imidodiphosphoric acids), bis(hydrazidodiphosphoric acids), poly(imidodiphosphoric acids), poly(hydrazidodiphosphoric acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for

- 20 Ce^{+4} include, but are not limited to: imidodiphosphoric acid, methylimidodiphosphoric acid, isopropylimidodiphosphoric acid, tert-butylimidodiphosphoric acid, phenylimidodiphosphoric acid, pentafluorophenylimidodiphosphoric acid, benzylimidodiphosphoric acid, cyclohexylimidodiphosphoric acid, norbornylimidodiphosphoric acid, dimethylimidodiphosphoric acid, diisopropylimidodiphosphoric acid, di-tert-butylimidodiphosphoric acid, diphenylimidodiphosphoric acid, di-pentafluorophenylimidodiphosphoric acid, dibenzylimidodiphosphoric acid, dicyclohexylimidodiphosphoric acid, and dinorbornylimidodiphosphoric acid.

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O Valence Stabilizer #16: Examples of imidodiphosphoramides, hydrazidodiphosphoramides,

- 30 bis(imidodiphosphoramides), bis(hydrazidodiphosphoramides), poly(imidodiphosphoramides), and poly(hydrazidodiphosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetridentates)

- that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: imidodiphosphoramide, N-methylimidodiphosphoramide, N-isopropylimidodiphosphoramide, N-tert-butylimidodiphosphoramide, N-phenylimidodiphosphoramide, N-pentafluorophenylimidodiphosphoramide, N-benzylimidodiphosphoramide, N-cyclohexylimidodiphosphoramide, N-norbornylimidodiphosphoramide, N,N'''-dimethylimidodiphosphoramide, N,N'''-diisopropylimidodiphosphoramide, N,N'''-di-tert-butylimidodiphosphoramide, N,N'''-diphenylimidodiphosphoramide, N,N'''-di-pentafluorophenylimidodiphosphoramide, N,N'''-dibenzylimidodiphosphoramide, N,N'''-dicyclohexylimidodiphosphoramide, and N,N'''-dinorbornylimidodiphosphoramide.

- O Valence Stabilizer #17: Examples of diphosphoramides, bis(diphosphoramides), and poly(diphosphoramides) (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 15 diphosphoramide, N-methyldiphosphoramide, N-isopropyldiphosphoramide, N-tert-butyldiphosphoramide, N-phenyldiphosphoramide, N-pentafluorophenyldiphosphoramide, N-benzoyldiphosphoramide, N-cyclohexyldiphosphoramide, N-norbornyldiphosphoramide, N,N'''-dimethyldiphosphoramide, N,N'''-diisopropyldiphosphoramide, N,N'''-di-tert-butyldiphosphoramide, N,N'''-diphenyldiphosphoramide, N,N'''-di-pentafluorophenyldiphosphoramide, N,N'''-dibenzoyldiphosphoramide, N,N'''-dicyclohexyldiphosphoramide, and N,N'''-dinorbornyldiphosphoramide.

- O Valence Stabilizer #18: Examples of beta-hydroxyketones, beta-hydroxyaldehydes, bis(beta-hydroxyketones), bis(beta-hydroxyaldehydes), poly(beta-hydroxyketones), and poly(beta-hydroxyaldehydes) (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 25 4-hydroxypentan-2-one; 1,3-diphenyl-3-hydroxypropanal; 1,3-dibenzyl-3-hydroxypropanal; 1,3-dicyclohexyl-3-hydroxypropanal; 1,3-dinorbornyl-3-hydroxypropanal; 1,3-di(2-thienyl)-3-hydroxypropanal; 1,3-di(2-furyl)-3-hydroxypropanal; o-hydroxyacetophenone; juglone; alizarin;
- 30 1-hydroxyanthraquinone; 1,8-hydroxyanthraquinone; 1-hydroxyacridone; and beta-hydroxybenzophenone.

O Valence Stabilizer #19: Examples of oxamides, bis(oxamides), and poly(oxamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: oxamide, N-methyloxamide; N-ethyloxamide; N-isopropyloxamide; N-phenyloxamide; N-benzyloxamide; N-

- 5 cyclohexyloxamide; N-norbornyloxamide; N,N'-dimethyloxamide; N,N'-diethyloxamide; N,N'-diisopropyloxamide; N,N'-diphenyloxamide; N,N'-dibenzyloxamide; N,N'-dicyclohexyloxamide; and N,N'-dinorbornyloxamide.

O Valence Stabilizer #20: Examples of squaric acids and derivatives thereof (O-O Bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: deltic acid; squaric acid; croconic acid; and rhodizonic acid.

- O Valence Stabilizer #21: Examples of dicarboxylic acids, bis(dicarboxylic acids), poly(dicarboxylic acids), and derivatives thereof (O-O Bidentates and O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: oxalic acid; malonic acid; succinic acid; diphenyl oxalate; diphenyl malonate; and diphenyl succinate.

- O Valence Stabilizer #22: Examples of carbonates and bis(carbonates) (O-O Bidentates and O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: carbonate; bicarbonate; O,O-diethylcarbonate; diisopropylcarbonate; diphenylcarbonate; dibenzylcarbonate; dicyclohexylcarbonate; and dinorbornylcarbonate.

- 25 O Valence Stabilizer #23: Examples of carbamates, bis(carbamates), and poly(carbamates) (including N-hydroxycarbamates and N-mercaptopcarbamates) (O-O Bidentates, O-O Tridentates, and O-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dimethylcarbamate (dmc); di(trifluorodimethyl)carbamate; ethyl carbamate; diethylcarbamate (dec); dipropylcarbamate; diisopropylcarbamate; 30 dibutylcarbamate; di-tert-butylcarbamate; dicyanamidocarbamate; diphenylcarbamate; di(pentafluorophenyl)carbamate; dibenzylcarbamate; dinaphthylcarbamate;

dicyclohexylcarbamate; dinorbornylcarbamate; diadamantylcarbamate; pyrrolidinocarbamate (pyrc); piperidinocarbamate (pipc); morpholinocarbamate (morc); thiamorpholinocarbamate; 3-pyrrolinocarbamate; pyrrolocarbamate; oxazolocarbamate; isoxazolocarbamate; thiazolocarbamate; isothiazolocarbamate; indolocarbamate; carbazolocarbamate;

5 pyrazolinocarbamate; imidazolinocarbamate; pyrazolocarbamate; imidazolocarbamate; indazolocarbamate; and triazolocarbamate.

O Valence Stabilizer #24: Examples of carbimates, bis(carbimates), and poly(carbimates) (O-O Bidentates, O-O Tridentates, and O-O Tetracentates) that meet the requirements for use as “wide

10 band” valence stabilizers for Ce^{+4} include, but are not limited to: methylcarbimate; trifluoromethylcarbimate; ethylcarbimate; propylcarbimate; isopropylcarbimate; butylcarbimate; tertbutylcarbimate; cyanocarbimate; cyanamidocarbimate; azidocarbimate; phenylcarbimate; pentafluorophenylcarbimate; benzylcarbimate; naphthylcarbimate; cyclohexylcarbimate; norbornylcarbimate; and adamantylcarbimate. [Note: carbimates tend to stabilize lower

15 oxidation states in metal ions.]

O Valence Stabilizer #25: Examples of N-(aminomethylol)ureas [N-(aminohydroxymethyl)ureas], bis[N-(aminomethylol)ureas], and poly[N-(aminomethylol)ureas] (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as

20 “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N’-(aminohydroxymethyl)urea; N,N’-dimethyl-N’-(aminohydroxymethyl)urea; N,N’-diethyl-N’-(aminohydroxymethyl)urea; N,N’-isopropyl-N’-(aminohydroxymethyl)urea; N,N’-diphenyl-N’-(aminohydroxymethyl)urea; N,N’-dibenzyl-N’-(aminohydroxymethyl)urea; N,N’-dicyclohexyl-N’-(aminohydroxymethyl)urea; and N,N’-dinorbornyl-N’-(aminohydroxymethyl)urea.

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O Valence Stabilizer #26: Examples of cyanate ligands (O monodentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: cyanate (-OCN).

30 N-S Valence Stabilizer #1: Examples of diformamidine disulfides (thioperoxydicarbonimidic diamides), thioperoxytricarbonimidic diamides, thioperoxytetracarbonimidic diamides,

bis(diformamidine disulfides), and poly(diformamidine disulfides) (N-S bidentates, N-N-S tridentates, or N-S tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diformamidine disulfide; methylformamidine disulfide; ethylformamidine disulfide; isopropylformamidine disulfide; 5 butylformamidine disulfide; benzylformamidine disulfide; phenylformamidine disulfide; tolylformamidine disulfide; naphthylformamidine disulfide; cyclohexylformamidine disulfide; norbornylformamidine disulfide; adamantylformamidine disulfide; dimethylformamidine disulfide; diethylformamidine disulfide; diisopropylformamidine disulfide; dibutylformamidine disulfide; dibenzylformamidine disulfide; 10 diphenylformamidine disulfide; ditolylformamidine disulfide; dinaphthylformamidine disulfide; dicyclohexylformamidine disulfide; dinorbornylformamidine disulfide; diadamantylformamidine disulfide; 2-S-amidinodisulfidothiazole; 2-S-amidinodisulfidooxazole; 2-S-amidinodisulfidoimidazole; 3-S-amidinodisulfidopyrazole; 3-S-amidinodisulfido-1,2,4-triazole; and 5-S-amidinodisulfidotetrazole.

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N-S Valence Stabilizer #2: Examples of S-amidinodithiocarbamates, bis(S-amidinodithiocarbamates), and poly(S-amidinodithiocarbamates) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: S-amidinodithiocarbamate; N-methyl-S-amidinodithiocarbamate; 20 N-ethyl-S-amidinodithiocarbamate; N-isopropyl-S-amidinodithiocarbamate; N-butyl-S-amidinodithiocarbamate; N-benzyl-S-amidinodithiocarbamate; N-phenyl-S-amidinodithiocarbamate; N-tolyl-S-amidinodithiocarbamate; N-naphthyl-S-amidinodithiocarbamate; N-cyclohexyl-S-amidinodithiocarbamate; N-norbornyl-S-amidinodithiocarbamate; N-adamantyl-S-amidinodithiocarbamate; N,N'-dimethyl-S- 25 amidinodithiocarbamate; N,N'-diethyl-S-amidinodithiocarbamate; N,N'-diisopropyl-S-amidinodithiocarbamate; N,N'-dibutyl-S-amidinodithiocarbamate; N,N'-dibenzyl-S-amidinodithiocarbamate; N,N'-diphenyl-S-amidinodithiocarbamate; N,N'-ditolyl-S-amidinodithiocarbamate; N,N'-dinaphthyl-S-amidinodithiocarbamate; N,N'-dicyclohexyl-S-amidinodithiocarbamate; N,N'-dinorbornyl-S-amidinodithiocarbamate; N,N'-diadamantyl-S- 30 amidinodithiocarbamate; ethylenebis(S-amidinodithiocarbamate); propylenebis(S-amidinodithiocarbamate); phenylenebis(S-amidinodithiocarbamate); piperazinebis(S-

amidinodithiocarbamate); oxalylbis(S-amidinodithiocarbamate); malonylbis(S-amidinodithiocarbamate); succinylbis(S-amidinodithiocarbamate); phthalylbis(S-amidinodithiocarbamate); 2-S-dithiocarbamatothiazole; 2-S-dithiocarbamatooxazole; 2-S-dithiocarbamatoimidazole; 3-S-dithiocarbamatopyrazole; 3-S-dithiocarbamato-1,2,4-triazole;
5 and 5-S-dithiocarbamatotetrazole.

N-S Valence Stabilizer #3: Examples of O-amidinothiocarbamates, bis(O-amidinothiocarbamates), and poly(O-amidinothiocarbamates) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}
10 include, but are not limited to: O-amidinothiocarbamate; N-methyl-O-amidinothiocarbamate; N-ethyl-O-amidinothiocarbamate; N-isopropyl-O-amidinothiocarbamate; N-butyl-O-amidinothiocarbamate; N-benzyl-O-amidinothiocarbamate; N-phenyl-O-amidinothiocarbamate; N-tolyl-O-amidinothiocarbamate; N-naphthyl-O-amidinothiocarbamate; N-cyclohexyl-O-amidinothiocarbamate; N-norbornyl-O-amidinothiocarbamate; N-adamantyl-O-
15 amidinothiocarbamate; N,N'-dimethyl-O-amidinothiocarbamate; N,N'-diethyl-O-amidinothiocarbamate; N,N'-diisopropyl-O-amidinothiocarbamate; N,N'-dibutyl-O-amidinothiocarbamate; N,N'-dibenzyl-O-amidinothiocarbamate; N,N'-diphenyl-O-amidinothiocarbamate; N,N'-ditolyl-O-amidinothiocarbamate; N,N'-dinaphthyl-O-amidinothiocarbamate; N,N'-dicyclohexyl-O-amidinothiocarbamate; N,N'-dinorbornyl-O-
20 amidinothiocarbamate; N,N'-diadamantyl-O-amidinothiocarbamate; ethylenebis(O-amidinothiocarbamate); propylenebis(O-amidinothiocarbamate); phenylenebis(O-amidinothiocarbamate); piperazinebis(O-amidinothiocarbamate); oxalylbis(O-amidinothiocarbamate); malonylbis(O-amidinothiocarbamate); succinylbis(O-amidinothiocarbamate); phthalylbis(O-amidinothiocarbamate); 2-O-monothiocarbamatothiazole;
25 2-O-monothiocarbamatooxazole; 2-O-monothiocarbamatoimidazole; 3-O-monothiocarbamatopyrazole; 3-O-monothiocarbamato-1,2,4-triazole; 5-O-monothiocarbamatotetrazole.

N-S Valence Stabilizer #4: Examples of S-amidinoperoxythiocarbamates, bis(S-amidinoperoxythiocarbamates), and poly(S-amidinoperoxythiocarbamates) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}
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include, but are not limited to: S-amidinoperoxythiocarbamate; N-methyl-S-amidinoperoxythiocarbamate; N-ethyl-S-amidinoperoxythiocarbamate; N-isopropyl-S-amidinoperoxythiocarbamate; N-butyl-S-amidinoperoxythiocarbamate; N-benzyl-S-amidinoperoxythiocarbamate; N-phenyl-S-amidinoperoxythiocarbamate; N-tolyl-S-amidinoperoxythiocarbamate; N-naphthyl-S-amidinoperoxythiocarbamate; N-cyclohexyl-S-amidinoperoxythiocarbamate; N-norbornyl-S-amidinoperoxythiocarbamate; N-adamantyl-S-amidinoperoxythiocarbamate; N,N'-dimethyl-S-amidinoperoxythiocarbamate; N,N'-diethyl-S-amidinoperoxythiocarbamate; N,N'-diisopropyl-S-amidinoperoxythiocarbamate; N,N'-dibutyl-S-amidinoperoxythiocarbamate; N,N'-dibenzyl-S-amidinoperoxythiocarbamate; N,N'-diphenyl-S-amidinoperoxythiocarbamate; N,N'-ditolyl-S-amidinoperoxythiocarbamate; N,N'-dinaphthyl-S-amidinoperoxythiocarbamate; N,N'-dicyclohexyl-S-amidinoperoxythiocarbamate; N,N'-dinorbornyl-S-amidinoperoxythiocarbamate; N,N'-diadamantyl-S-amidinoperoxythiocarbamate; ethylenebis(S-amidinoperoxythiocarbamate); propylenebis(S-amidinoperoxythiocarbamate); phenylenebis(S-amidinoperoxythiocarbamate); piperazinebis(S-amidinoperoxythiocarbamate); oxalylbis(S-amidinoperoxythiocarbamate); malonylbis(S-amidinoperoxythiocarbamate); succinylbis(S-amidinoperoxythiocarbamate); and phthalylbis(S-amidinoperoxythiocarbamate).

N-S Valence Stabilizer #5: Examples of phosphorimidothioic acid; phosphorimidodithioic acid; phosphorimidotrithioic acid; bis(phosphorimidothioic acid); bis(phosphorimidodithioic acid); bis(phosphorimidotrithioic acid); poly(phosphorimidothioic acid); poly(phosphorimidodithioic acid); poly(phosphorimidotrithioic acid); and derivatives thereof (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphorimidothioic acid; phosphorimidodithioic acid; phosphorimidotrithioic acid; O-phenylphosphorimidothioic acid; O-benzylphosphorimidothioic acid; O-cyclohexylphosphorimidothioic acid; O-norbornylphosphorimidothioic acid; O,O'-diphenylphosphorimidothioic acid; O,O'-dibenzylphosphorimidothioic acid; O,O'-dicyclohexylphosphorimidothioic acid; and O,O'-dinorbornylphosphorimidothioic acid.

N-S Valence Stabilizer #6: Examples of phosphorothioic triamides, bis(phosphorothioic triamides), and poly(phosphorothioic triamides) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not

limited to: phosphorothioic triamide; phosphorothioic trihydrazide; phosphoramidothioic dihydrazide; N-phenylphosphorothioic triamide; N-benzylphosphorothioic triamide; N-cyclohexylphosphorothioic triamide; N-norbornylphosphorothioic triamide; N,N'-diphenylphosphorothioic triamide; N,N'-dibenzylphosphorothioic triamide; N,N'-dicyclohexylphosphorothioic triamide; and N,N'-dinorbornylphosphorothioic triamide.

N-S Valence Stabilizer #7: Examples of phosphoramidotrithioic acid, phosphorodiamidodithioic acid, bis(phosphoramidotrithioic acid), bis(phosphorodiamidodithioic acid), poly(phosphoramidotrithioic acid), poly(phosphorodiamidodithioic acid), and derivatives thereof (N-S Bidentates and N-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidotrithioic acid, phosphorodiamidodithioic acid, S-phenylphosphoramidotrithioic acid, S-benzylphosphoramidotrithioic acid, S-cyclohexylphosphoramidotrithioic acid, S-norbornylphosphoramidotrithioic acid, S,S'-diphenylphosphoramidotrithioic acid, S,S'-dibenzylphosphoramidotrithioic acid, S,S'-dicyclohexylphosphoramidotrithioic acid, and S,S'-dinorbornylphosphoramidotrithioic acid.

N-S Valence Stabilizer #8: Examples of phosphoramidothioic acid, phosphoramidodithioic acid, phosphorodiamidothioic acid, bis(phosphoramidothioic acid), bis(phosphoramidodithioic acid), bis(phosphorodiamidothioic acid), poly(phosphoramidothioic acid), poly(phosphoramidodithioic acid), and poly(phosphorodiamidothioic acid) (N-S Bidentates and N-S Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidothioic acid, phosphoramidodithioic acid, phosphorodiamidothioic acid, phosphorohydrazidothioic acid, phosphorohydrazidodithioic acid, phosphorodihydrazidothioic acid, phosphoramidothioic acid, O-phenylphosphoramidothioic acid, O-benzylphosphoramidothioic acid, O-cyclohexylphosphoramidothioic acid, O-norbornylphosphoramidothioic acid, S-phenylphosphoramidodithioic acid, S-benzylphosphoramidodithioic acid, S-cyclohexylphosphoramidodithioic acid, and S-norbornylphosphoramidodithioic acid.

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N-S Valence Stabilizer #9: Examples of N-thioacyl 7-aminobenzylidenimines (N-S Bidentates or N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-thioacetyl 7-methylaminobenzylidenimine; N-thioacetyl 7-phenylaminobenzylidenimine; N-thiobenzoyl 7-methylaminobenzylidenimine; and N-

5 thiobenzoyl 7-phenylaminobenzylidenimine.

N-S Valence Stabilizer #10: Examples of thiohydroxamates (thiohydroxylamines), bis(thiohydroxamates), and poly(thiohydroxamates) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

10 include, but are not limited to: acetothiohydroxamic acid; propionothiohydroxamic acid; butyrothiohydroxamic acid; crotonothiohydroxamic acid; sorbothiohydroxamic acid; benzothiohydroxamic acid; toluicthiohydroxamic acid; salicylthiohydroxamic acid; phenylacetothiohydroxamic acid; anthranilthiohydroxamic acid; nicotinethiohydroxamic acid; picolinethiohydroxamic acid; cyclohexanethiohydroxamic acid; quinoline 8-thiohydroxamic
15 acid; cinnamylthiohydroxamic acid; oxaldithiohydroxamic acid; succinylbis-N-phenylthiohydroxamic acid; adipylbis-N-phenylthiohydroxamic acid; glyoxalthiohydroxamic acid; 2-thiophenethiocarbohydroxamic acid; thenoylthiohydroxamic acid; N-phenylbenzothiohydroxamic acid; N-tolylbenzothiohydroxamic acid; N-phenylacetothiohydroxamic acid; N-phenyl-2-thenoylthiohydroxamic acid; and N-tolyl-2-
20 thenoylthiohydroxamic acid.

N-S Valence Stabilizer #11: Examples of alpha- or ortho-aminothiocarboxylic acids, and alpha- or ortho-aminothiodicarboxylic acids, and derivatives thereof (N-S Bidentates, N-S Tridentates, and N-S Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for
25 Ce^{+4} include, but are not limited to: 2-pyridinethiocarboxylic acid (thiopicolinic acid); 2-pyrazinethiocarboxylic acid; o-aminothiobenzoic acid; o-aminothionaphthoic acid; and 3,6-diaminothiophthalic acid.

N-S Valence Stabilizer #12: Examples of thiosemicarbazones, bis(thiosemicarbazones), and
30 poly(thiosemicarbazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited

- to: acetaldehyde thiosemicarbazone; acetone thiosemicarbazone; pinacolone thiosemicarbazone; benzaldehyde thiosemicarbazone; naphthaldehyde thiosemicarbazone; norbornanone thiosemicarbazone; camphor thiosemicarbazone; nopinone thiosemicarbazone; 2-pyridinaldehyde thiosemicarbazone; salicylaldehyde thiosemicarbazone; quinolinaldehyde thiosemicarbazone; isatin dithiosemicarbazone; camphorquinone dithiosemicarbazone; camphorquinone dithiosemicarbazone; picolinaldehyde thiosemicarbazone; dipyridyl glyoxal dithiosemicarbazone; di-2-pyridyl ketone thiosemicarbazone; methyl-2-pyridyl ketone thiosemicarbazone; glyoxal dithiosemicarbazone; acetophenone thiosemicarbazone; biacetyl monoxime thiosemicarbazone; acetamidobenzaldehyde thiosemicarbazone; thymolalldothiosemicarbazone; thiophene-2-aldehyde thiosemicarbazone; phthalaldehyde dithiosemicarbazone; phthalimide dithiosemicarbazone; furaldehyde thiosemicarbazone; naphthoquinone thiosemicarbazone; phenanthrequinone thiosemicarbazone; cyclohexanedione dithiosemicarbazone; ionone thiosemicarbazone; bithiosemicarbazone of diethyl-3,4-dioxadioate; pyridoxal alkylthiosemicarbazones; benzylidene phenylthiosemicarbazones; lawsone thiosemicarbazone; and 1-benzoin-4-phenylthiosemicarbazone (bps).

- N-S Valence Stabilizer #13: Examples of thioacyl hydrazones, bis(thioacyl hydrazones), and poly(thioacyl hydrazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetaldehyde N-thioformylhydrazone; acetaldehyde N-thiobenzoylhydrazone; acetone N-thioformylhydrazone; acetone N-thiobenzoylhydrazone; pinacolone N-thioformylhydrazone; pinacolone N-thiobenzoylhydrazone; benzaldehyde N-thioformylhydrazone; benzaldehyde N-thiobenzoylhydrazone; naphthaldehyde N-thioformylhydrazone; naphthaldehyde N-thiobenzoylhydrazone; norbornanone N-thioformylhydrazone; norbornanone N-thiobenzoylhydrazone; camphor N-thioformylhydrazone; camphor N-thiobenzoylhydrazone; nopinone N-thioformylhydrazone; nopinone N-thiobenzoylhydrazone; 2-pyridinaldehyde N-thioformylhydrazone; 2-pyridinaldehyde N-thiobenzoylhydrazone; salicylaldehyde N-thioformylhydrazone; salicylaldehyde N-thiobenzoylhydrazone; quinolinaldehyde N-thioformylhydrazone; quinolinaldehyde N-thiobenzoylhydrazone; thiophene-2-aldehyde N-thioformylhydrazone; thiophene-2-aldehyde N-thiobenzoylhydrazone; naphthoquinone N-thioformylhydrazone; naphthoquinone N-thiobenzoylhydrazone; ionone N-thioformylhydrazone;

ionone N-thiobenzoylhydrazone; benzaldehyde benzothiazolehydrazone; lawsone N-thioformylhydrazone; and lawsone N-thiobenzoylhydrazone.

N-S Valence Stabilizer #14: Examples of thiocarbazones (diazene-carbothioic hydrazides),

- 5 bis(thiocarbazones), and poly(thiocarbazones) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diphenylthiocarbazone (dithizone); 2-phenylthiocarbazone; dinaphthylthiocarbazone; 2-naphthylthiocarbazone; and ambazone.

- 10 N-S Valence Stabilizer #15: Examples of azo compounds with thiol or mercapto or thiocarbonyl substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis[o-(HS-) or alpha- or beta-(HS-)azo compounds], or Poly[o-(HS-) or alpha- or beta-(HS-)azo compounds] (N-S Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-
- 15 thiolazobenzene [1-(phenylazo)-2-thiophenol]; 2,2'-dithioazobenzene; (2-thiophene)azobenzene; 1-(4-nitrophenylazo)-2-thionaphthol; 2-thiazolylazobenzene; and 2-benzothiazolylazobenzene.

N-S Valence Stabilizer #16: Examples of diazeneformothioamides, diazeneacetothioamides, bis(diazeneformothioamides), bis(diazeneacetothioamides), poly(diazeneformothioamides), and

20 poly(diazeneacetothioamides) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformothioamide, diazeneacetothioamide, phenyldiazeneformothioamide, diphenyldiazeneformothioamide, phenyldiazeneacetothioamide, and diphenyldiazeneacetothioamide.

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N-S Valence Stabilizer #17: Examples of diazenecarbothioic acids, diazenecarbodithioic acids, bis(diazene-carbothioic acids), bis(diazene-carbodithioic acids), poly(diazene-carbothioic acids), poly(diazene-carbodithioic acids) and derivatives thereof (N-S Bidentates, N-S Tetradentates, N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

30 include, but are not limited to: diazeneformothioic acid, diazeneacetothioic acid,

phenyldiazeneformothioic acid, diphenyldiazeneformothioic acid, phenyldiazeneacetothioic acid, and diphenyldiazeneacetothioic acid.

N-S Valence Stabilizer #18: Examples of diazeneformothioaldehydes,

- 5 diazeneacetothioaldehydes, bis(diazeneformothioaldehydes), bis(diazeneacetothioaldehydes), poly(diazeneformothioaldehydes), and poly(diazeneacetothioaldehydes) (N-S Bidentates, N-S Tetridentates and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformothioaldehyde, diazeneacetothioaldehyde, phenyldiazeneformothioaldehyde, 10 diphenyldiazeneformothioaldehyde, phenyldiazeneacetothioaldehyde, and diphenyldiazeneacetothioaldehyde.

N-S Valence Stabilizer #19: Examples of diazenediformothioamides, diazenediacetothioamides, bis(diazenediformothioamides), bis(diazenediacetothioamides),

- 15 poly(diazenediformothioamides), and poly(diazenediacetothioamides) (N-S Tridentates and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformodithioamide, diazenediacetodithioamide, diphenyldiazenediformodithioamide, tetraphenyldiazenediformodithioamide, diphenyldiazenediacetodithioamide, and tetraphenyldiazenediacetodithioamide.

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N-S Valence Stabilizer #20: Examples of diazenedicarbothioic acids, diazenedicarbodithioic acids, bis(diazenedicarbothioic acids), bis(diazenedicarbodithioic acids),

- poly(diazenedicarbothioic acids), poly(diazenedicarbodithioic acids) and derivatives thereof (N-S Tridentates and N-S Hexadentates) that meet the requirements for use as “wide band” valence 25 stabilizers for Ce^{+4} include, but are not limited to: diazenediformothioic acid, diazenediacetodithioic acid, phenyldiazenediformothioic acid, diphenyldiazenediformothioic acid, phenyldiazenediacetodithioic acid, and diphenyldiazenediacetodithioic acid.

N-S Valence Stabilizer #21: Examples of diazenediformothioaldehydes,

- 30 diazenediacetothioaldehydes, bis(diazenediformothioaldehydes), bis(diazenediacetothioaldehydes), poly(diazenediformothioaldehydes), and

poly(diazenediacetothioaldehydes) (N-S Tridentates and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediiformothioaldehyde, diazenediacetothioaldehyde, diphenyldiazenediiformothioaldehyde, and diphenyldiazenediacetothioaldehyde.

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N-S Valence Stabilizer #22: Examples of ortho-thio (or -mercapto) substituted formazans, bis(o-thio or -mercapto substituted formazans), and poly(o-thio or -mercapto substituted formazans) (N-S Bidentates, N-S Tridentates, N-S Tetracentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

10 1-(2-thiophenyl)-3,5-diphenylformazan; 1-(2-methylmercaptophenyl)-3,5-diphenylformazan; 1,5-bis(2-thiophenyl)-3-phenylformazan; and 5-bis(2-methylmercaptophenyl)-3-phenylformazan.

N-S Valence Stabilizer #23: Examples of ortho-thio (or -mercapto) substituted azines (including

15 ketazines), bis(o-thio or mercapto substituted azines), and poly(o-thio or mercapto substituted azines) (N-S Bidentates, N-S Tridentates, N-S Tetracentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercapto-1-benzalazine; 2-mercapto-1-naphthalazine; and 2-mercapto-1-cyclohexanonazine.

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N-S Valence Stabilizer #24: Examples of Schiff Bases with one Imine ($C=N$) Group and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Bidentates, N-S Tridentates, N-S Tetracentates, N-S Pentadentates, or N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

25 N-(Thiosalicylaldehydo)isopropylamine; N-(2-thiophenecarboxaldehydo)isopropylamine; N-(2-Acetylthiopheno)isopropylamine; N-(2-Thioacetophenono)isopropylamine; N-(Thiosalicylaldehydo)cyclohexylamine; N-(2-Thiophenecarboxaldehydo)cyclohexylamine; N-(2-Acetylthiopheno)cyclohexylamine; N-(2-Thioacetophenono)cyclohexylamine; N-(Thiosalicylaldehydo)aniline; N-(2-Thiophenecarboxaldehydo)aniline; N-(2-Acetylthiopheno)aniline; N-(2-Thioacetophenono)aniline; N-

30 (Thiosalicylaldehydo)aminonorborene; N-(2-Thiocarboxaldehydo)aminonorborene; N-(2-

- Acetylthiopheno)aminonorbornane; N-(2-Thioacetophenono)aminonorbornane; 4-aminobenzylidene-3-propyl-5-mercapto-1,2,4-triazole; 4-aminocinnamalidene-3-propyl-5-mercapto-1,2,4-triazole (acpmt); 4-aminosalicylidene-3-propyl-5-mercapto-1,2,4-triazole (aspmt); 4-aminovanillidene-3-propyl-5-mercapto-1,2,4-triazole; 4-aminodimethylaminobenzylidene-3-propyl-5-mercapto-1,2,4-triazole (adpmt); cinnamylideneaminophenylthiazole; N-(2-mercaptophenyl)salicylidenimine; 2-thiophenecarboxaldehyde phenylhydrazone; 2-thiophenecarboxaldehyde 2-pyridyl hydrazone; 2-mercaptobenzaldehyde phenylhydrazone; and 2-mercaptobenzaldehyde 2-pyridyl hydrazone. Also includes Schiff Bases derived from the reaction of carbonyl compounds with
- 10 dithiocarbazates, and hydrazones with ortho-S substitution.

- N-S Valence Stabilizer #25: Examples of Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Tridentates, N-S Tetradentates, N-S Pentadentates, or N-S Hexadentates) that meet the requirements for use as
- 15 “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N’-(2,5-Thiophenedicarboxaldehydo)diisopropylamine; N,N’-(2,5-Thiophenedicarboxaldehydo)dicyclohexylamine; N,N’-(2,5-Thiophenedicarboxaldehydo)dianiline; N,N’-(2,5-Thiophenedicarboxaldehydo)di-aminonorbornane; N,N’-(o-Thiophthalicdialdehydo)diisopropylamine; N,N’-(o-Thiophthalicdialdehydo)dicyclohexylamine; N,N’-(o-Thiophthalicdialdehydo)dianiline; N,N’-(o-Thiophthalicdialdehydo)di-aminonorbornane; N,N’-(o-Thioformylcamphoro)diisopropylamine; N,N’-(o-Thioformylcamphoro)dicyclohexylamine; N,N’-(o-Thioformylcamphoro)dianiline; N,N’-(o-Thioformylcamphoro)di-aminonorbornane; N,N’-(o-Thiodiacetylbenzeno)diisopropylamine; N,N’-(o-Thiodiacetylbenzeno)dicyclohexylamine; N,N’-
- 20 (o-Thiodiacetylbenzeno)dianiline; N,N’-(o-Thiodiacetylbenzeno)di-aminonorbornane; N,N’-(3,6-Dithio-1,2-cyclohexanono)diisopropylamine; N,N’-(3,6-Dithio-1,2-cyclohexanono)dicyclohexylamine; N,N’-(3,6-Dithio-1,2-cyclohexanono)dianiline; N,N’-(3,6-Dithio-1,2-cyclohexanono)di-aminonorbornane; N,N’-(2,5-Diacetylthiopheno)diisopropylamine; N,N’-(2,5-Diacetylthiopheno)dicyclohexylamine; N,N’-(2,5-Diacetylthiopheno)dianiline; N,N’-
- 25 (2,5-Diacetylthiopheno)di-aminonorbornane; N,N’-(Thiosalicylaldehydo)ethylenediamine; N,N’-(o-Thionaphthaldehydo)ethylenediamine; N,N’-(o-Thioacetophenono)ethylenediamine; ;
- 30

- N,N'-(Thiosalicylaldehydo)trimethylenediamine; N,N'-(o-Thionaphthaldehydo)trimethylenediamine; N,N'-(o-Thioacetophenono)trimethylenediamine; ; N,N'-(Thiosalicylaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Thionaphthaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Thioacetophenono)cyclohexane-1,2-diamine; N,N'-(Thiosalicylaldehydo)-1,2-diaminobenzene; N,N'-(o-Thionaphthaldehydo)-1,2-diaminobenzene; and N,N'-(o-Thioacetophenono)-1,2-diaminobenzene. Also includes Schiff Bases derived from the reaction of carbonyl compounds with dithiocarbazates, and hydrazones with ortho-S substitution.
- 10 N-S Valence Stabilizer #26: Examples of Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-thio or mercapto or thiocarbonyl substitution (N-S Tetradentates, N-S Pentadentates, or N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N',N''-(Thiosalicylaldehydo)tris(2-aminoethyl)amine; N,N',N''-(o-Thionaphthaldehydo)tris(2-aminoethyl)amine; and N,N',N''-(o-Thioacetophenono)tris(2-aminoethyl)amine. Also includes Schiff Bases derived from the reaction of carbonyl compounds with dithiocarbazates, and hydrazones with ortho-S substitution.
- N-S Valence Stabilizer #27: Examples of thioalkyl amines (aminothiols or aminodisulfides) and thioalkyl imines (iminothiols or iminodisulfides) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercapto-1-aminoethane; 2-methylmercapto-1-aminoethane; 3-mercapto-1-aminopropane; 1-mercapto-2-amino-2-methylpropane; 2-mercaptocyclohexylamine; 3-mercapto-2-aminonorbornane; 1,3-dimercapto-2-aminopropane; 1,5-dimercapto-3-aminopentane; 2,2'-diaminodiethyl sulfide; 3,3'-diaminodipropyl sulfide; 2,2'-diaminodicyclohexyl sulfide; 1,6-dimercapto-3,4-diaminohexane; 1,7-dimercapto-3,5-diaminoheptane; 1,6-diamino-3,4-dimercaptohexane; 1,7-diamino-3,5-dimercaptoheptane; tri(mercaptomethyl)amine; tri(2-mercaptoethyl)amine; dithiooxamide (rubeanic acid); 2,2'-diaminodiethyl disulfide; 3,3'-diaminodipropyl disulfide; 2,2'-diaminodicyclohexyl disulfide; 3-amino-1,5-pentanedithiodialdehyde; 3,4-diamino-1,6-hexanedithiodialdehyde; 3,5-diamino-1,7-heptanedithiodialdehyde; iminobisacetic acid; iminobispropionic acid; and bis(hydroxyethyl)aminoalkyl sulfide.

N-S Valence Stabilizer #28: Examples of thioaryl amines and thioaryl imines (N-S Bidentates, N-S Tridentates, N-S Tetracentates, and N-S Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminothiophenol (2-aminobenzenethiol); 2-aminothiobenzoic acid (thioanthranilic acid); 2-aminothioanisole; 2-
 5 (methanamine)benzyl mercaptan [(2-aminomethyl)-alpha-toluenethiol] [(2-mercaptomethyl)-alpha-aminotoluene]; 1-amino-2-naphthalenethiol; 2-amino-1-naphthalenethiol; 2-amino-1-(methylthio)benzene; 2,2'-di(aminomethyl)diphenylthioketone; di(2-amino)phenyl sulfide; di(2-amino)phenyl disulfide (di-ortho-aminophenyl disulfide (doapd)); 1,3-di(2-amino)phenyl-2-mercaptopropane; 1,3-di(3-amino)phenyl-2-mercaptopropane; 1,3-di(2-mercapto)phenyl-2-
 10 aminopropane; 1,3-di(3-mercapto)phenyl-2-aminopropane; 2,2'-dimercaptoiminodibenzyl; 2,2'-iminodibenzothioic acid; 2,2'-dimercaptoiminostilbene; and poly(o-aminothiophenol).

N-S Valence Stabilizer #29: Examples of five-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional sulfur atom binding site not in a
 15 ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercaptopyrrole; 2-(methylthio)methylpyrrole; 2,5-(thiomethyl)pyrrole; 2,5-(methylthiomethyl)pyrrole; 2,6-(methylthio)pyrrole; imidazoline-2-thione (2-mercaptimidazole); 2-mercaptothiazoline; 2-mercaptobenzimidazole; 2-mercaptobenzothiazole;
 20 2-mercaptobenzoxazole; 2-thiohydantoin; di-2-pyridylthioglyoxal (2,2'-thiopyridil); bis((1-pyrazolyl)methane)sulfide; bis((1-pyrazolyl)methane)disulfide; bis(2-(1-pyrazolyl)ethane)sulfide; bis(2-(1-pyrazolyl)ethane)disulfide; bis(benzimidazolylmethane)sulfide; bis(benzimidazolylethane)sulfide; bis(benzimidazolylmethane)disulfide; bis(benzimidazolylethane)disulfide;
 25 tris(imidazolyl)methanethiol; tris(imidazolylmethane)methanethiol; N-thiomethyl-N,N-(benzimidazolylmethane)amine; N-(2-thioethyl)-N,N-(benzimidazolylmethane)amine; N,N'-di(benzimidazolylmethane)-1,3-diamino-2-mercaptopropane; N,N,N',N'-tetrakis(benzimidazolylmethane)-1,3-diamino-2-mercaptopropane; bis(N,N-((4-imidazolyl)methane)2-aminoethane)sulfide; bis(N,N-((4-imidazolyl)methane)2-
 30 aminoethane)disulfide; 2-aminobenzothiazole (abt); 2-phenylaminothiazole; thiohydantoin; thioxohydropyrazole; 2-mercaptobenzothiazole (mbt); 2-mercapto-1,3,4-thiadiazole; 2,5-

dimercapto-1,3,4-thiadiazole (bismuthiol); 2,5-bis(alkylthio)-1,3,4-thiadiazole; 2-amino-5-
 mercapto-1,3,4-thiadiazole (amt); 5-mercaptotetrazole; 1-phenyl-5-mercaptotetrazole (pmt)(5-
 mptt); 5-mercaptotriazole; 3-mercaptotriazole; (2-benzothiazolyl)thioacetic acid; (2-
 benzothiazolyl)thiopropionic acid; (alkylthio)benzotriazoles; (arylthio)benzotriazoles; 2-
 5 mercaptopyrimidine; bis(5-mercapto-1,2,4-triazol-3-yl); bis(5-mercapto-1,2,4-triazol-3-
 yl)alkanes; 2-aminothiazolidine; thiazolidine-2-thione; 2-mercaptothiazolidine; 1-(2-
 mercaptoethyl)imidazoline; imidazolidine-2-thione; 4,5-dihydroxyimidazolidine-2-thione; 4-
 amino-5-mercapto-1,2,4-triazole; (2-benzimidazolylthio)carboxylic acids; (2-
 benzoxazolylthio)carboxylic acids; (2-benzothiazolylthio)carboxylic acids; (2-
 10 benzimidazolylthio)hydroxyalkyl(aryl)s; (2-benzoxazolylthio)hydroxyalkyl(aryl)s; (2-
 benzothiazolylthio)hydroxyalkyl(aryl)s; 2-(phenylmethylthio)benzothiazole; 2,5-
 bis(hydrocarbyldithio)-1,3,4-thiadiazoles; 2-(hydrocarbyldithio)-5-mercapto-1,3,4-thiadiazoles;
 bis(dithiobisthiadiazole); benzothiazolethione; 3-hydrazino-5-thio-1,2,4-triazole; imidazolidine-
 2,4-dithione; dimercaptobenzothiazole; 2-aminothiazole (atz); thiadiazole-2-thione; 5-
 15 mercaptothiadiazole-2-thione; 1,1-thiocarbonyldiimidazole; phosphosphonomethylenethio-1,3-
 benzothiazole (pmtbt); 4,5-dihydroxyimidazolidine-2-thione; imidazolidine-2-thione; 1,1'-
 thiocarbonyldiimidazole; 2,2'-dithiobis(benzothiazole); and 5,5'-dithiobis(tetrazole).

N-S Valence Stabilizer #30: Examples of six-membered heterocyclic rings containing one, two,
 20 three, or four nitrogen atoms and having at least one additional sulfur atom binding site not in a
 ring (N-S Bidentates, N-S Tridentates, N-S Tetridentates, or N-S Hexadentates) that meet the
 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
 4-aminomethyl-3-pyridinemethanethiol (including thiopyridoxamine); 2-mercaptopyridine; 2-
 (methylthio)methylpyridine; 2-(2-(methylthio)ethyl)pyridine; 2,6-(thiomethyl)pyridine; 2,6-
 25 (methylthiomethyl)pyridine; 2,6-(methyldisulfidomethyl)pyridine; 2-mercaptopyrimidine; 2-
 dithiomethylpyrimidine; 2-mercaptoquinoline; 8-mercaptoquinoline (thioxine); 8-
 methylthioquinoline; 2-mercaptoquinazoline; thioorotic acid (1,2,3,6-tetrahydro-2,6-dithiono-4-
 pyrimidinecarboxylic acid) (6-thiouracilcarboxylic acid); 1-methylpyrimidine-2-thione; 2-
 thiouracil; 2,4-dithiouracil; 6-mercaptopurine; bis(N,N,N',N'-tetra(2-(2-
 30 pyridyl)ethane)aminomethane)sulfide; bis(N,N,N',N'-tetra(2-(2-
 pyridyl)ethane)aminomethane)disulfide; bis(N,N,N',N'-tetra(2-(2-

pyridyl)ethane)aminoethane)sulfide; bis(N,N,N',N'-tetra(2-(2-pyridyl)ethane)aminoethane)disulfide; 1,3,5-triazine-6-thione; 2-benzylmercapto-1,3,5-triazine; triazine dithiols [i.e., 6-(phenylamino)-1,3,5-triazine-2,4-dithiol (ptd); 6-aniline-1,3,5-triazine-2,4-dithiol (atd); and 2-(N,N-dialkylamino)-1,3,5-triazine-4,6-dithiol]; 2-thioquinazoline; 2-
5 thioquinazolin-4-one; thiomorpholin-3-thione; [2-(aminomethyl)thio]pyridine; 6-mercaptapurine; dithiouracil; and 2,2'-dithiodipyridine (2,2'-dipyridyl disulfide).

N-S Valence Stabilizer #31: Examples of five-membered heterocyclic rings containing one or two sulfur atoms and having at least one additional nitrogen atom binding site not in a ring (N-S
10 Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexacentates) that meet the requirements for use as "wide band" valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminothiophene; 2,5-diaminothiophene; 2-aminomethylthiophene; 2,5-di(aminomethyl)thiophene; 2-aminobenzothiophene; and 2-iminothiolane.

15 N-S Valence Stabilizer #32: Examples of six-membered heterocyclic rings containing one or two sulfur atoms and having at least one additional nitrogen atom binding site not in a ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexacentates) that meet the requirements for use as "wide band" valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminothiopyran; 2,6-diaminothiopyran; 2-aminomethylthiopyran; 2,6-di(aminomethyl)thiopyran;
20 and 2-aminobenzothiopyran.

N-S Valence Stabilizer #33: Examples of five-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional sulfur atom binding site in a separate ring (N-S Bidentates, N-S Tridentates, N-S Tetracentates) that meet the requirements
25 for use as "wide band" valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-thiophene)pyrrole; 2,5-di(2-thiophene)pyrrole; 2-(2-thiopyran)pyrrole; 2,5-di(2-thiopyran)pyrrole; 2,5-di(2-pyrrole)thiophene; 2,6-di(2-pyrrole)thiopyran; and 3,5-bis(2-thienyl)-4-amino-1,2,4-triazole (2-tat).

30 N-S Valence Stabilizer #34: Examples of six-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional sulfur atom binding site in a

separate ring (N-S Bidentates, N-S Tridentates, N-S Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-thiadiazolyl)benzimidazole; 2-(2-thiophene)pyridine; 2,6-di(2-thiophene)pyridine; 2-(2-thiopyran)pyridine; 2,6-di(2-thiopyran)pyridine; 2,5-di(2-pyridyl)thiophene; 2,6-di(2-pyridyl)thiopyran; and 2-(4-thiazolyl)benzimidazole.

N-S Valence Stabilizer #35: Examples of two-, three-, four-, six-, eight-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) or sulfur (usually thiols, mercaptans, or thiocarbonyls) and are not contained in component heterocyclic rings (N-S Bidentates, N-S Tridentates, N-S Tetridentates, and N-S Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: azathiacyclobutane ([4]aneNS); azathiacyclopentane ([5]aneNS); azathiacyclohexane ([6]aneNS); azathiacycloheptane ([7]aneNS); azathiacyclooctane ([8]aneNS); azathiacyclobutene ([4]eneNS); azathiacyclopentene ([5]eneNS); azathiacyclohexene ([6]eneNS); azathiacycloheptene ([7]eneNS); azathiacyclooctene ([8]eneNS); azathiacyclobutadiene ([4]dieneNS); azathiacyclopentadiene ([5]dieneNS); azathiacyclohexadiene ([6]dieneNS); azathiacycloheptadiene ([7]dieneNS); azathiacyclooctadiene ([8]dieneNS); diazathiacyclohexane ([6]aneSN₂); diazathiacycloheptane ([7]aneSN₂); diazathiacyclooctane ([8]aneSN₂); diazathiacyclononane ([9]aneSN₂); diazathiacyclodecane ([10]aneSN₂); diazathiacycloundecane ([11]aneSN₂); diazathiacyclododecane ([12]aneSN₂); diazathiacyclohexene ([6]eneSN₂); diazathiacycloheptene ([7]eneSN₂); diazathiacyclooctene ([8]eneSN₂); diazathiacyclononene ([9]eneSN₂); diazathiacyclodecene ([10]eneSN₂); diazathiacycloundecene ([11]eneSN₂); diazathiacyclododecene ([12]eneSN₂); diazadithiacyclooctane ([8]aneS₂N₂); diazadithiacyclononane ([9]aneS₂N₂); diazadithiacyclodecane ([10]aneS₂N₂); diazadithiacycloundecane ([11]aneS₂N₂); diazadithiacyclododecane ([12]aneS₂N₂); diazadithiacyclotridecane ([13]aneS₂N₂); diazadithiacyclotetradecane ([14]aneS₂N₂); diazadithiacyclopentadecane ([15]aneS₂N₂); diazadithiacyclohexadecane ([16]aneS₂N₂); diazadithiacycloheptadecane ([17]aneS₂N₂); diazadithiacyclooctadecane ([18]aneS₂N₂); diazadithiacyclononadecane ([19]aneS₂N₂); diazadithiacycloeicosane ([20]aneS₂N₂);

- diazadithiacyclooctadiene ([8]dieneS₂N₂); diazadithiacyclononadiene ([9]dieneS₂N₂);
diazadithiacyclodecadiene ([10]dieneS₂N₂); diazadithiacycloundecadiene ([11]dieneS₂N₂);
diazadithiacyclododecadiene ([12]dieneS₂N₂); diazadithiacyclotridecadiene ([13]dieneS₂N₂);
diazadithiacyclotetradecadiene ([14]dieneS₂N₂); diazadithiacyclopentadecadiene
5 ([15]dieneS₂N₂); diazadithiacyclohexadecadiene ([16]dieneS₂N₂);
diazadithiacycloheptadecadiene ([17]dieneS₂N₂); diazadithiacyclooctadecadiene
([18]dieneS₂N₂); diazadithiacyclononadecadiene ([19]dieneS₂N₂); diazadithiacycloeicosadiene
([20]dieneS₂N₂); and tetramethyldithiahexaazacyclobidecanehexaene (mtab).
- 10 N-S Valence Stabilizer #36: Examples of four-, six-, eight-, or ten-membered macrocyclics,
macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and
sepulchrates) wherein all binding sites are composed of nitrogen or sulfur and are contained in
component heterocyclic rings (N-S Bidentates, N-S Tridentates, N-S Tetracentates, or N-S
Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce⁺⁴
15 include, but are not limited to: dithiopyrandipyridines; dithiophenedipyrroles;
trithiopyrantripyrindines; trithiophenetripyrroles; tetrathiopyrantetrapyrindines; and
tetrathiophenetetrapyrroles.
- N-S Valence Stabilizer #37: Examples of four-, six-, eight-, or ten-membered macrocyclics,
20 macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and
sepulchrates) wherein all binding sites are composed of nitrogen or sulfur and are contained in a
combination of heterocyclic rings and amine, imine, thiol, mercapto, or thiocarbonyl groups (N-S
Bidentates, N-S Tridentates, N-S Tetracentates, or N-S Hexacentates) that meet the requirements
for use as “wide band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
25 azathiatetraphyrins; diazadithiatetraphyrins; azathiahexaphyrins; diazadithiahexaphyrins; and
triazatrithiahexaphyrins.
- N-O Valence Stabilizer #1: Examples of N-hydroxy(or N,N'-dihydroxy)amidines and N-
hydroxy(or N,N'-dihydroxy)diamidines (N-O bidentates, N-O tridentates, or N-O tetracentates)
30 that meet the requirements for use as “wide band” valence stabilizers for Ce⁺⁴ include, but are
not limited to: N-hydroxy-N,N'-dimethylformamidine; N-hydroxy-N,N'-diethylformamidine; N-

- hydroxy-N,N'-diisopropylformamidine; N-hydroxy-N,N'-dibutylformamidine; N-hydroxy-N,N'-diphenylformamidine; N-hydroxy-N,N'-dibenzylformamidine; N-hydroxy-N,N'-dinaphthylformamidine; N-hydroxy-N,N'-dicyclohexylformamidine; N-hydroxy-N,N'-dinorbornylformamidine; N-hydroxy-N,N'-diadamantylformamidine; N-hydroxy-N,N'-dianthraquinonylformamidine; N-hydroxy-N,N'-dimethylacetamidine; N-hydroxy-N,N'-diethylacetamidine; N-hydroxy-N,N'-diisopropylacetamidine; N-hydroxy-N,N'-dibutylacetamidine; N-hydroxy-N,N'-diphenylacetamidine; N-hydroxy-N,N'-dibenzylacetamidine; N-hydroxy-N,N'-dinaphthylacetamidine; N-hydroxy-N,N'-dicyclohexylacetamidine; N-hydroxy-N,N'-dinorbornylacetamidine; N-hydroxy-N,N'-diadamantylacetamidine; N-hydroxy-N,N'-dimethylbenzamidine; N-hydroxy-N,N'-diethylbenzamidine; N-hydroxy-N,N'-diisopropylbenzamidine; N-hydroxy-N,N'-dibutylbenzamidine; N-hydroxy-N,N'-diphenylbenzamidine; N-hydroxy-N,N'-dibenzylbenzamidine; N-hydroxy-N,N'-dinaphthylbenzamidine; N-hydroxy-N,N'-dicyclohexylbenzamidine; N-hydroxy-N,N'-dinorbornylbenzamidine; N-hydroxy-N,N'-diadamantylbenzamidine; N-hydroxy-N,N'-dimethyltoluamidine; N-hydroxy-N,N'-diethyltoluamidine; N-hydroxy-N,N'-diisopropyltoluamidine; N-hydroxy-N,N'-dibutyltoluamidine; N-hydroxy-N,N'-diphenyltoluamidine; N-hydroxy-N,N'-dibenzyltoluamidine; N-hydroxy-N,N'-dinaphthyltoluamidine; N-hydroxy-N,N'-dicyclohexyltoluamidine; N-hydroxy-N,N'-dinorbornyltoluamidine; N-hydroxy-N,N'-diadamantyltoluamidine; N,N'-dihydroxyoxalic diamidine; N,N'-dihydroxymalonic diamidine; N,N'-dihydroxysuccinic diamidine; N,N'-dihydroxyglutaric diamidine; N,N'-dihydroxyadipic diamidine; N,N'-dihydroxypimelic diamidine; N,N'-dihydroxysuberic diamidine; N,N'-dihydroxyphthalic diamidine; N,N'-dihydroxyterephthalic diamidine; N,N'-dihydroxyisophthalic diamidine; N,N'-dihydroxypiperazine diamidine.

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N-O Valence Stabilizer #2: Examples of guanylureas, guanidinoureas, bis(guanylureas), bis(guanidinoureas), poly(guanylureas), and poly(guanidinoureas) (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: guanylurea (amidinourea)(dicyandiamidine); guanidinourea; methylguanylurea; ethylguanylurea; isopropylguanylurea; butylguanylurea; benzylguanylurea; phenylguanylurea; tolylguanylurea; naphthylguanylurea; cyclohexylguanylurea;

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- norbornylguanyllurea; adamantylguanyllurea; dimethylguanyllurea; diethylguanyllurea; diisopropylguanyllurea; dibutylguanyllurea; dibenzylguanyllurea; diphenylguanyllurea; ditolylguanyllurea; dinaphthylguanyllurea; dicyclohexylguanyllurea; dinorbornylguanyllurea; diadamantylguanyllurea; ethylenebis(guanyllurea); propylenebis(guanyllurea);
- 5 phenylenebis(guanyllurea); piperazinebis(guanyllurea); oxalylbis(guanyllurea); malonylbis(guanyllurea); succinylbis(guanyllurea); phthalylbis(guanyllurea); 2-ureidothiazole; 2-ureidooxazole; 2-ureidoimidazole; 3-ureidopyrazole; 3-ureido-1,2,4-triazole; and 5-ureidotetrazole.
- 10 N-O Valence Stabilizer #3: Examples of amidinoamides, guanidinoamides, bis(amidinoamides), bis(guanidinoamides), poly(amidinoamides), and poly(guanidinoamides) (including both N-amidinoamides and 2-amidinoacetamides) (N-O Bidentates, N-O Tridentates, and N-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: amidinoacetamide (1-acetylguanidine); guanidinoacetamide;
- 15 amidinopropanamide; amidinobutanamide; amidinobenzamide; amidinotoluamide; amidinocyclohexamide; N-methylamidinoacetamide; N-ethylamidinopropanamide; N-propylamidinobutanamide; N-phenylamidinobenzamide; N-tolylamidinotoluamide; N-cyclohexylamidinocyclohexamide; bis(amidinoacetamide); bis(amidinomalonicamide); bis(amidinotetracarboxylicamide); bis(amidinophthalicamide); 2-amidinoacetamide (malonamidine); N-
- 20 methyl-2-amidinoacetamide; N-ethyl-2-amidinoacetamide; N-phenyl-2-amidinoacetamide; N-benzyl-2-amidinoacetamide; N-cyclohexyl-2-amidinoacetamide; N,N'-dimethyl-2-amidinoacetamide; N,N'-diethyl-2-amidinoacetamide; N,N'-diphenyl-2-amidinoacetamide; N,N'-dibenzyl-2-amidinoacetamide; N,N'-dicyclohexyl-2-amidinoacetamide; 2-N-acylaminothiazole; 2-N-acylaminooxazole; 2-N-acylaminoimidazole; 3-N-acylaminopyrazole; 3-
- 25 N-acylamino-1,2,4-triazole; and 5-N-acylaminotetrazole.

- N-O Valence Stabilizer #4: Examples of imidoamides, bis(imidoamides), and poly(imidoamides) (N-O Bidentates, N-O Tridentates, and N-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 30 acetimidoylacetamide; acetimidoylpropanamide; acetimidoylbutanamide; acetimidoylbenzamide; acetimidoyltoluamide; acetimidoylcyclohexamide;

propimidoylpropanamide; butimidoylbutanamide; benzimidoylbenzamide;
ethylenebis(acetimidoylacetamide); propylenebis(acetimidoylacetamide); and
phenylenebis(acetimidoylacetamide).

- 5 N-O Valence Stabilizer #5: Examples of O-amidinocarbamates, bis(O-amidinocarbamates), and
poly(O-amidinocarbamates) (N-O Bidentates and N-O Tetradentates) that meet the requirements
for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: O-
amidinocarbamate; N-methyl-O-amidinocarbamate; N-ethyl-O-amidinocarbamate; N-isopropyl-
O-amidinocarbamate; N-butyl-O-amidinocarbamate; N-benzyl-O-amidinocarbamate; N-phenyl-
10 O-amidinocarbamate; N-tolyl-O-amidinocarbamate; N-naphthyl-O-amidinocarbamate; N-
cyclohexyl-O-amidinocarbamate; N-norbornyl-O-amidinocarbamate; N-adamantyl-O-
amidinocarbamate; N,N'-dimethyl-O-amidinocarbamate; N,N'-diethyl-O-amidinocarbamate;
N,N'-diisopropyl-O-amidinocarbamate; N,N'-dibutyl-O-amidinocarbamate; N,N'-dibenzyl-O-
amidinocarbamate; N,N'-diphenyl-O-amidinocarbamate; N,N'-ditolyl-O-amidinocarbamate;
15 N,N'-dinaphthyl-O-amidinocarbamate; N,N'-dicyclohexyl-O-amidinocarbamate; N,N'-
dinorbornyl-O-amidinocarbamate; N,N'-diadamantyl-O-amidinocarbamate; ethylenebis(O-
amidinocarbamate); propylenebis(O-amidinocarbamate); phenylenebis(O-amidinocarbamate);
piperazinebis(O-amidinocarbamate); oxalylbis(O-amidinocarbamate); malonylbis(O-
amidinocarbamate); succinylbis(O-amidinocarbamate); phthalylbis(O-amidinocarbamate); 2-O-
20 carbamatothiazole; 2-O-carbamatooxazole; 2-O-carbamatoimidazole; 3-O-carbamatopyrazole; 3-
O-carbamato-1,2,4-triazole; and 5-carbamatotetrazole.

- N-O Valence Stabilizer #6: Examples of S-amidinothiocarbamates, bis(S-
amidinothiocarbamates), and poly(S-amidinothiocarbamates) (N-O Bidentates and N-O
25 Tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}
include, but are not limited to: S-amidinothiocarbamate; N-methyl-S-amidinothiocarbamate; N-
ethyl-S-amidinothiocarbamate; N-isopropyl-S-amidinothiocarbamate; N-butyl-S-
amidinothiocarbamate; N-benzyl-S-amidinothiocarbamate; N-phenyl-S-amidinothiocarbamate;
N-tolyl-S-amidinothiocarbamate; N-naphthyl-S-amidinothiocarbamate; N-cyclohexyl-S-
30 amidinothiocarbamate; N-norbornyl-S-amidinothiocarbamate; N-adamantyl-S-
amidinothiocarbamate; N,N'-dimethyl-S-amidinothiocarbamate; N,N'-diethyl-S-

amidinothiocarbamate; N,N'-diisopropyl-S-amidinothiocarbamate; N,N'-dibutyl-S-amidinothiocarbamate; N,N'-dibenzyl-S-amidinothiocarbamate; N,N'-diphenyl-S-amidinothiocarbamate; N,N'-ditolyl-S-amidinothiocarbamate; N,N'-dinaphthyl-S-amidinothiocarbamate; N,N'-dicyclohexyl-S-amidinothiocarbamate; N,N'-dinorbornyl-S-amidinothiocarbamate; N,N'-diadamantyl-S-amidinothiocarbamate; ethylenebis(S-amidinothiocarbamate); propylenebis(S-amidinothiocarbamate); phenylenebis(S-amidinothiocarbamate); piperazinebis(S-amidinothiocarbamate); oxalylbis(S-amidinothiocarbamate); malonylbis(S-amidinothiocarbamate); succinylbis(S-amidinothiocarbamate); phthalylbis(S-amidinothiocarbamate); 2-O-monothiocarbamatothiazole; 2-O-monothiocarbamatooxazole; 2-O-monothiocarbamatoimidazole; 3-O-monothiocarbamatopyrazole; 3-O-monothiocarbamato-1,2,4-triazole; and 5-O-monothiocarbamatotetrazole.

N-O Valence Stabilizer #7: Examples of diimidosulfuric acid, bis(diimidosulfuric acid), and derivatives thereof (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diimidosulfuric acid; O-phenyldiimidosulfuric acid; O-benzoyldiimidosulfuric acid, O-cyclohexyldiimidosulfuric acid, O-norbornyldiimidosulfuric acid, O,O'-diphenyldiimidosulfuric acid; O,O'-dibenzoyldiimidosulfuric acid, O,O'-dicyclohexyldiimidosulfuric acid, and O,O'-dinorbornyldiimidosulfuric acid.

N-O Valence Stabilizer #8: Examples of phosphorimidic acid, bis(phosphorimidic acid); and poly(phosphorimidic acid), and derivatives thereof (N-O Bidentates, N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphorimidic acid; O-phenylphosphorimidic acid; O-benzylphosphorimidic acid; O-cyclohexylphosphorimidic acid; O-norbornylphosphorimidic acid; O,O'-diphenylphosphorimidic acid; O,O'-dibenzylphosphorimidic acid; O,O'-dicyclohexylphosphorimidic acid; and O,O'-dinorbornylphosphorimidic acid.

N-O Valence Stabilizer #9: Examples of phosphoric triamides, bis(phosphoric triamides), and poly(phosphoric triamides) (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoric

triamide; phosphoramidic dihydrazide; N-phenylphosphoric triamide, N-benzylphosphoric triamide; N-cyclohexylphosphoric triamide; N-norbornylphosphoric triamide; N,N'-diphenylphosphoric triamide, N,N'-dibenzylphosphoric triamide; N,N'-dicyclohexylphosphoric triamide; and N,N'-dinorbornylphosphoric triamide.

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N-O Valence Stabilizer #10: Examples of phosphoramidic acid, phosphorodiamidic acid, bis(phosphoramidic acid), bis(phosphorodiamidic acid), poly(phosphoramidic acid), poly(phosphorodiamidic acid), and derivatives thereof (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphoramidic acid, phosphorodiamidic acid, phosphoramidohydrazidic acid; phosphorohydrazidic acid; phosphorodihydrazidic acid; O-phenylphosphoramidic acid; O-benzylphosphoramidic acid; O-cyclohexylphosphoramidic acid; O-norbornylphosphoramidic acid; O,O'-diphenylphosphoramidic acid; O,O'-dibenzylphosphoramidic acid; O,O'-dicyclohexylphosphoramidic acid; and O,O'-dinorbornylphosphoramidic acid.

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N-O Valence Stabilizer #11: Examples of N-acyl 7-aminobenzylidenimines (N-O Bidentates or N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-acetyl 7-methylaminobenzylidenimine; N-acetyl 7-phenylaminobenzylidenimine; N-benzoyl 7-methylaminobenzylidenimine; and N-benzoyl 7-phenylaminobenzylidenimine.

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N-O Valence Stabilizer #12: Examples of oximes, dioximes, and poly(oximes) (N-O Bidentates, N-O Tridentates, and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetaldoxime (Hado); acetoxime (acetone oxime)(Hato); butanone oxime; pentanone oxime; hexanone oxime; pinacolone oxime; heptanone oxime; octanone oxime; cyclopentanone oxime; cyclohexanone oxime; cycloheptanone oxime; cyclooctanone oxime; cyclopentanedione dioxime; cyclohexanedione dioxime; cycloheptanedione dioxime; cyclooctanedione dioxime; isatin dioxime; benzaldehyde oxime; naphthaldehyde oxime; norbornanone oxime; camphor oxime; dimethylglyoxime (H₂DMG); diethylglyoxime; diisopropylglyoxime; ditertbutylglyoxime; dicyanoglyoxime; dicyanamidoglyoxime; diphenylglyoxime (Hdfg); dibenzylglyoxime; dicyclohexylglyoxime;

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dinorbornylglyoxime; camphorquinone dioxime (Hcqd); nopinoquinone dioxime (Hnqd); butyraldioxime; propionaldioxime; furildioxime; and thienyldioxime.

N-O Valence Stabilizer #13: Examples of carbonyl oximes, bis(carbonyl oximes), and

- 5 poly(carbonyl oximes) (N-O Bidentates, N-O Tridentates, and N-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diacetyl monoxime (2,3-butanedione monoxime); benzil monoxime (1,2-diphenylethanedione monoxime); 1,2-dicyclohexylethanedione monoxime; 1,2-(trifluoromethyl)ethanedione monoxime; 1,2-dinorbornylethanedione monoxime; cyclopentanedione monoxime;
- 10 cyclohexanedione monoxime; cycloheptanedione monoxime; cyclooctanedione monoxime; camphorquinone oxime; 3-hydroxyiminopentane-2,4-dione; and 4-isonitrosopyralozone.

N-O Valence Stabilizer #14: Examples of imine oximes, bis(imine oximes), and poly(imine oximes) (including 2-nitrogen heterocyclic oximes) (N-O Bidentates, N-O Tridentates, N-O

- 15 Tetridentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-(methylimino)butan-2-one oxime; 4-(methylimino)hexan-3-one oxime; 1,2-diphenyl-2-(methylimino)ethan-1-one oxime; 1,2-diphenyl-2-(phenylimino)ethan-1-one oxime; 1,2-dicyclohexyl-2-(methylimino)ethan-1-one oxime; 1,2-dicyclohexyl-2-(cyclohexylimino)ethan-1-one oxime; 1,2-dinorbornyl-2-
- 20 (methylimino)ethan-1-one oxime; N,N'-methylenebis-(3-iminobutan-2-one oxime); N,N'-methylenebis-(4-iminohexan-3-one oxime); N,N'-methylenebis-(1,2-diphenyl-2-iminoethan-1-one oxime); N,N'-methylenebis-(1,2-dicyclohexyl-2-iminoethan-1-one oxime); N,N'-methylenebis-(1,2-dinorbornyl-2-iminoethan-1-one oxime); N,N'-ethylenebis-(3-iminobutan-2-one oxime); N,N'-ethylenebis-(4-iminohexan-3-one oxime); N,N'-ethylenebis-(1,2-diphenyl-2-
- 25 iminoethan-1-one oxime); N,N'-ethylenebis-(1,2-dicyclohexyl-2-iminoethan-1-one oxime); N,N'-ethylenebis-(1,2-dinorbornyl-2-iminoethan-1-one oxime); N,N'-propylenebis-(3-iminobutan-2-one oxime); N,N'-propylenebis-(4-iminohexan-3-one oxime); N,N'-propylenebis-(1,2-diphenyl-2-iminoethan-1-one oxime); N,N'-propylenebis-(1,2-dicyclohexyl-2-iminoethan-1-one oxime); N,N'-propylenebis-(1,2-dinorbornyl-2-iminoethan-1-one oxime); diacetylazine
- 30 oxime (Hazio); 2-pyridinaldioxime (Hpao); methyl 2-pyridyl ketone oxime; ethyl 2-pyridyl ketoxime; phenyl 2-pyridyl ketone oxime (Hppk); benzyl 2-pyridyl ketoxime; di(2-pyridyl)

ketone oxime; methyl 2-pyrrolyl ketone oxime; ethyl 2-pyrrolyl ketone oxime; phenyl 2-pyrrolyl ketone oxime; di(2-pyrrolyl) ketone oxime; and tris(2-aldoximo-6-pyridyl)phosphine..

N-O Valence Stabilizer #15: Examples of hydroxy oximes, bis(hydroxy oximes), and

- 5 poly(hydroxy oximes) (including 2-oxygen heterocyclic oximes) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-hydroxybutan-2-one oxime; 4-hydroxyhexan-3-one oxime; benzoin oxime (bo)(1,2-diphenyl-2-hydroxyethanone oxime); 1,2-di(trifluoromethyl)-2-hydroxyethanone oxime; 1,2-dicyclohexyl-2-hydroxyethanone oxime; 1,2-dinorbornyl-2-hydroxyethanone oxime; salicylaldoxime (so)(saldox); 2-hydroxy-1-naphthaldehyde oxime; 2-furanaldoxime; furildioxime; methyl 2-furanyl ketone oxime; ethyl 2-furanyl ketoxime; phenyl 2-furanyl ketone oxime; benzyl 2-furanyl ketoxime; di(2-furanyl) ketone oxime; and 2,5-(oximinomethyl)phenol.

- 15 N-O Valence Stabilizer #16: Examples of amino oximes, bis(amino oximes), and poly(amino oximes) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-(methylamino)butan-2-one oxime (HMeabo); 4-(methylamino)hexan-3-one oxime (HEtabo); 1,2-diphenyl-2-(methylamino)ethanone oxime (HPhabo); 1,2-diphenyl-2-(phenylamino)ethanone oxime; 1,2-dicyclohexyl-2-(methylamino)ethanone oxime (HcyHxabo); 1,2-dicyclohexyl-2-(cyclohexylamino)ethanone oxime; 1,2-di(trifluoromethyl)-2-(methylamino)ethanone oxime; 1,2-dinorbornyl-2-(methylamino)ethanone oxime (HNorbabo); N,N'-ethylenebis-(3-aminobutan-2-one oxime)(Haboen); N,N'-ethylenebis-(4-aminohexan-3-one oxime); N,N'-ethylenebis-(1,2-diphenyl-2-aminoethanone oxime); N,N'-ethylenebis-(1,2-dicyclohexyl-2-aminoethanone oxime); N,N'-ethylenebis-(1,2-di(trifluoromethyl)-2-aminoethanone oxime); N,N'-ethylenebis-(1,2-dinorbornyl-2-aminoethanone oxime); N,N'-propylenebis-(3-aminobutan-2-one oxime)(Habopn); N,N'-propylenebis-(4-aminohexan-3-one oxime); N,N'-propylenebis-(1,2-diphenyl-2-aminoethanone oxime); N,N'-propylenebis-(1,2-dicyclohexyl-2-aminoethanone oxime); N,N'-propylenebis-(1,2-di(trifluoromethyl)-2-aminoethanone oxime); N,N'-propylenebis-(1,2-dinorbornyl-2-aminoethanone oxime); 2,2'-iminobis(acetamidoxime); 1-diethylamino-3-butanoxime; and di-2-pyridyl ketone oxime.

N-O Valence Stabilizer #17: Examples of amido oximes, bis(amido oximes), and poly(amido oximes) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: formamide oxime; acetamide oxime; propanamide oxime; butanamide oxime; benzamide
5 oxime (Hbamox); naphthamide oxime; diformamide dioxime; salicylamide oxime; and 4-imidazolamide oxime.

N-O Valence Stabilizer #18: Examples of azo oximes, bis(azo oximes), and poly(azo oximes) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the
10 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetaldehyde phenylhydrazone oxime; propionaldehyde phenylhydrazone oxime; and benzaldehyde phenylhydrazone oxime. Also includes hydrazone oximes.

N-O Valence Stabilizer #19: Examples of 2-nitrosophenols (o-quinone monoximes) (N-O
15 Bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-nitrosophenol; 1-nitroso-2-naphthol (Honn); 2-nitroso-1-naphthol (Htnn); 3-nitrosopyrocatechol; 3,6-dinitrosopyrocatechol; 2-nitrosoresorcinol; 2,4-dinitrosoresorcinol; 2,4,6-trinitrosoresorcinol; 2-nitrosohydroquinone; 2,6-dinitrosohydroquinone; 2,3,5,6-tetranitrosohydroquinone; 4-nitrosopyrogallol; 4,6-dinitrosopyrogallol; 2-nitrosophloroglucinol; 2,4,6-trinitrosophloroglucinol; 7-nitroso-6-hydroxyindazole; Pigment Green 12 (C.I. 10020); Naphthol Green; and nitroso-R-salt.
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N-O Valence Stabilizer #20: Examples of 2-nitrophenols (N-O Bidentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
25 2-nitrophenol; 2,3-dinitrophenol; 2,4-dinitrophenol; 2,5-dinitrophenol; 2,6-dinitrophenol; 2,4,6-trinitrophenol (picric acid); 2-amino-4,6-dinitrophenol (picramic acid); 1-nitro-2-naphthol; 2-nitro-1-naphthol; 3-nitropycatechol; 3,6-dinitropycatechol; 2-nitroresorcinol; 2,4-dinitroresorcinol; 2,4,6-trinitroresorcinol (styphnic acid); 2-nitrohydroquinone; 2,6-dinitrohydroquinone; 2,3,5,6-tetranitrohydroquinone; 4-nitropycogallol; 4,6-dinitropycogallol; 2-nitrophloroglucinol; 2,4,6-trinitrophloroglucinol; dinitrocresol; 7-nitro-6-hydroxyindazole; Dinoseb; Eosin; Naphthol Yellow; and Martius Yellow.
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N-O Valence Stabilizer #21: Examples of hydroxamates (hydroxylamines), bis(hydroxamates), and poly(hydroxamates) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetohydroxamic acid; propionohydroxamic acid; butyrohdroxamic acid;

- 5 crotonohydroxamic acid; sorbohdroxamic acid; benzohydroxamic acid (BH_2);
toluichydroxamic acid; salicylhydroxamic acid (SH_2); phenylacetohydroxamic acid (PhH_2);
anthranilhydroxamic acid (AnH_2); nicotinehydroxamic acid ($NicH_2$); picolinehydroxamic acid;
cyclohexanehydroxamic acid (CH_2); quinoline 8-hydroxamic acid (QH_2); cinnamylhydroxamic
acid (CnH_2); oxalldihydroxamic acid ($OxalH_2$); succinylbis-N-phenylhydroxamic acid (SuH_2);
10 adipylbis-N-phenylhydroxamic acid (AdH_2); glyoxalhydroxamic acid (GH_2); 2-
thiophenecarbohdroxamic acid; thenoylhydroxamic acid; N-phenylbenzohydroxamic acid; N-
tolylbenzohydroxamic acid; N-phenylacetohydroxamic acid; N-phenyl-2-thenoylhydroxamic
acid; N-tolyl-2-thenoylhydroxamic acid; and polyhydroxamic acids.

- 15 N-O Valence Stabilizer #22: Examples of N-nitrosohydroxylamines, bis(N-
nitrosohydroxylamines), and poly(N-nitrosohydroxylamines) (N-O Bidentates, N-O
Tetradentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence
stabilizers for Ce^{+4} include, but are not limited to: N-nitrosophenylhydroxylamine (cupferron);
N-nitrosonaphthylhydroxylamine (neocupferron); N-nitrosoanthracylhydroxylamine; N-
20 nitroso(2-pyridyl)hydroxylamine; and N-nitroso(2-thiophenyl)hydroxylamine.

- N-O Valence Stabilizer #23: Examples of amino acids, ortho-aminocarboxylic acids, peptides,
polypeptides, and proteins [N-O Bidentates, N-O Tridentates, and N-O Tetradentates; possibly S-
O dentates for sulfur-contg. examples such as penicillamine and cystine] that meet the
25 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:
alanine (Ala); arginine (Arg); asparagine (Asn); aspartic acid (Asp); cysteine (Cys); cystine (Cys
or Cys.Cys); dihydroxyphenylalanine (Dopa); glutamic acid (Glu); glutamine (Gln); glycine
(Gly); histidine (His); isoleucine (Ile); leucine (Leu); lysine (Lys); methionine (Met);
penicillamine (Pen); phenylalanine (Phe); tolylalanine (tala); proline (Pro); sarcosine; serine
30 (Ser); threonine (Thr); tryptophan (Trp); tyrosine (Tyr); and valine (Val) as amino acid
examples; 2-pyridinecarboxylic acid (picolinic acid), 2-pyrazinecarboxylic acid, 2,3-

dicarboxypyrazine, and anthranilic acid as ortho-aminocarboxylic acid examples; Gly-GluO; Hgly-Gly; Gly-MetO; Met-GlyO; Gly-TyrO; Ala-HisO; Gly-His-GlyO; Gly-Gly-His; Gly-Leu-TyrO; penta-GlyO; His-His; triaminoisobutyrate; tetra-GlyO; Pro-Gly; and Gly-Met as peptide examples; and azurin, carbonic anhydrase C; carboxypeptidase; concanavalin A; cytochrome b; 5 cytochrome c; erythrocyruorin; ferredoxin; haemerythrin; haemoglobin; myoglobin; parvalbumin; albumin; plastocyanin; rubredoxin; superoxide dismutase; thermolysin; and trysin as protein examples; N-acylamino acids; aminocaproic acid; and 3,5-diiodotyrosine.

N-O Valence Stabilizer #24: Examples of amides, bis(amides), and poly(amides), including 10 lactams (N-O bidentates, N-O tridentates, and N-O tetradentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetamide; propionamide; butanamide; benzamide (benzoylamide)(1-phenylformamide); 1-naphthylformamide; toluamide; 1-cyclohexylformamide); 1-norbornylformamide; 1-adamantylformamide; N,N-dimethylformamide (DMF)(DMFA); N,N-dimethylacetamide 15 (DMAC); N,N-dimethylbenzamide; N,N-diethylformamide; N,N-diethylacetamide; decanamide; dodecanamide; tetradecanamide; hexadecanamide; octadecanamide; lactobionic acid amide; (hydroxyalkylthio)succinamides; (mercaptoalkoxy)succinamides; bis(1,1'-benzotriazolyl)dicarboxamide; nicotinamide; acetanilide (N-phenylacetamide); formanilide (N-phenylformamide); benzanilide (N-phenylbenzamide); polycaproamides; glycineamide; 20 aminoalkylanilides; amidopolyamines (apa); bis(1-phenylethylamide); oxalic semiamide; malonic semiamide; succinic semiamide; N-methylformanilide; acetanilide; nicotinanilide; 4'-hydroxyacetanilide (acetaminophen); 2-pyrrolidone; methyl-2-pyrrolidone (NMP); 2-piperidone (valerolactam); caprolactam; polymethylenepolyamine dipropionamide; polyacrylamides; polypyrrolidones [including polyvinylpyrrolidone (povidone)(PVP)]; pyrazolidinones; 25 pyrazolones; diazepinones; N-alkylazaalkene lactams; and N-(2-hydroxyalkyl)azaalkene lactams.

N-O Valence Stabilizer #25: Examples of semicarbazones, bis(semicarbazones), and poly(semicarbazones) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates) that meet the 30 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetaldehyde semicarbazone; acetone semicarbazone; pinacolone semicarbazone; benzaldehyde

semicarbazone; naphthaldehyde semicarbazone; norbornanone semicarbazone; camphor semicarbazone; nopinone semicarbazone; 2-pyridinaldehyde semicarbazone; salicylaldehyde semicarbazone; quinolinaldehyde semicarbazone; isatin disemicarbazone; camphorquinone disemicarbazone; camphorquinone disemicarbazone; picolinaldehyde semicarbazone; dipyrindyl
5 glyoxal disemicarbazone; di-2-pyridyl ketone semicarbazone; methyl-2-pyridyl ketone semicarbazone; glyoxal disemicarbazone; acetophenone semicarbazone; biacetyl monoxime semicarbazone; acetamidobenzaldehyde semicarbazone; thymolaldosemicarbazone; thiophene-2-aldehyde semicarbazone; phthalaldehyde disemicarbazone; phthalimide disemicarbazone; furaldehyde semicarbazone; naphthoquinone semicarbazone; phenanthrequinone semicarbazone;
10 cyclohexanedione disemicarbazone; ionone semicarbazone; bisemicarbazone of diethyl-3,4-dioxadioate; and lawsone semicarbazone.

N-O Valence Stabilizer #26: Examples of acyl hydrazones, bis(acyl hydrazones), and poly(acyl hydrazones) (N-O Bidentates, N-O Tetridentates, and N-O Hexadentates) that meet the
15 requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: acetaldehyde N-formylhydrazone; acetaldehyde N-benzoylhydrazone; acetone N-formylhydrazone; acetone N-benzoylhydrazone; pinacolone N-formylhydrazone; pinacolone N-benzoylhydrazone; benzaldehyde N-formylhydrazone; benzaldehyde N-benzoylhydrazone; naphthaldehyde N-formylhydrazone; naphthaldehyde N-benzoylhydrazone; norbornanone N-
20 formylhydrazone; norbornanone N-benzoylhydrazone; camphor N-formylhydrazone; camphor N-benzoylhydrazone; nopinone N-formylhydrazone; nopinone N-benzoylhydrazone; 2-pyridinaldehyde N-formylhydrazone; 2-pyridinaldehyde N-benzoylhydrazone; salicylaldehyde N-formylhydrazone; salicylaldehyde N-benzoylhydrazone; quinolinaldehyde N-formylhydrazone; quinolinaldehyde N-benzoylhydrazone; furan-2-aldehyde N-formylhydrazone;
25 furan-2-aldehyde N-benzoylhydrazone; naphthoquinone N-formylhydrazone; naphthoquinone N-benzoylhydrazone; ionone N-formylhydrazone; ionone N-benzoylhydrazone; lawsone N-formylhydrazone; and lawsone N-benzoylhydrazone.

N-O Valence Stabilizer #27: Examples of carbazones (diazene-carboxylic hydrazides),
30 bis(carbazones), and poly(carbazones) (N-O Bidentates, N-O Tetridentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4}

include, but are not limited to: diphenylcarbazone; 2-phenylcarbazone; dinaphthylcarbazone; and 2-naphthylcarbazone.

- N-O Valence Stabilizer #28: Examples of azo compounds with hydroxyl or carboxy or carbonyl substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis[o-(HO-) or alpha- or beta-(HO-)azo compounds], or Poly[o-(HO-) or alpha- or beta-(HO-)azo compounds] (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxyazobenzene [1-(phenylazo)-2-phenol]; 2,2'-dihydroxyazobenzene (o,o'-dihydroxyazobenzene); (2-furan)azobenzene; Direct Blue 2B; 1-(4-nitrophenylazo)-2-naphthol; 1-(2-hydroxyphenylazo)-2-naphthol; 1-(2-methoxyphenylazo)-2-naphthol; pyridineazo-2-naphthol (PAN); pyridineazoresorcinol (PAR); 1-phenyl-4-(2-hydroxyphenylazo)-5-pyrazolone; 1-phenyl-4-(2-methoxyphenylazo)-5-pyrazolone; o-hydroxy-o'-(beta-aminoethylamino)azobenzene; 2-hydroxy-2'-methoxymethyleneoxyazobenzene; methyl red; turquoise blue (reactive blue); sunset yellow; amaranth; tartrazine; Eriochrome Black T; tropeolins; Allura Red; amaranth; Acid Alizarin Violet N; Acid Blue 29; Acid Orange 8, 63, and 74; Acid Red 1, 4, 8, 37, 88, 97, 114, 151, and 183; Acid Violet 7; Acid Yellow 25, 29, 34, 42, 76, and 99; Brilliant Black BN; Brilliant Crocein; Bordeaux R; Calcion; Chicago Sky Blue; Chromotrope; Cibacron Brilliant Red; Cibacron Brilliant Yellow; Crocein Orange; Crystal Scarlet; Calmagite; Direct Blue 71; Direct Red 23, 80, and 81; Direct Violet 51; Direct Yellow 8 and 27; Fast Black; Flavazin; Mordant Blue 9; Mordant Brown 1 and 33; Naphthol Blue Black; New Coccine; Nitrazine Yellow; Nitrosulfonazo III; Orange II; Orange G, OT, and B; Ponceau 3R and SX; Polar Yellow; 2-oxazolylazobenzene; and 2-benzoxazolylazobenzene.
- N-O Valence Stabilizer #29: Examples of diazeneformamides, diazeneacetamides, bis(diazeneformamides), bis(diazeneacetamides), poly(diazeneformamides), and poly(diazeneacetamides) (N-O Bidentates, N-O Tetracentates, and N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformamide, diazeneacetamide, phenyldiazeneformamide, diphenyldiazeneformamide, phenyldiazeneacetamide, and diphenyldiazeneacetamide.

N-O Valence Stabilizer #30: Examples of diazeneformic acids, diazeneacetic acids, bis(diazeneformic acids), bis(diazeneacetic acids), poly(diazeneformic acids), poly(diazeneacetic acids) and derivatives thereof (N-O Bidentates, N-O Tetridentates, N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformic acid, diazeneacetic acid, phenyldiazeneformic acid, diphenyldiazeneformic acid, phenyldiazeneacetic acid, and diphenyldiazeneacetic acid.

N-O Valence Stabilizer #31: Examples of diazeneformaldehydes, diazeneacetaldehydes, bis(diazeneformaldehydes), bis(diazeneacetaldehydes), poly(diazeneformaldehydes), and poly(diazeneacetaldehydes) (N-O Bidentates, N-O Tetridentates and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazeneformaldehyde, diazeneacetaldehyde, phenyldiazeneformaldehyde, diphenyldiazeneformaldehyde, phenyldiazeneacetaldehyde, and diphenyldiazeneacetaldehyde.

N-O Valence Stabilizer #32: Examples of diazenediformamides, diazenediacetamides, bis(diazenediformamides), bis(diazenediacetamides), poly(diazenediformamides), and poly(diazenediacetamides) (N-O Tridentates and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformamide, diazenediacetamide, diphenyldiazenediformamide, tetraphenyldiazenediformamide, diphenyldiazenediacetamide, and tetraphenyldiazenediacetamide.

N-O Valence Stabilizer #33: Examples of diazenediformic acids, diazenediacetic acids, bis(diazenediformic acids), bis(diazenediacetic acids), poly(diazenediformic acids), poly(diazenediacetic acids) and derivatives thereof (N-O Tridentates and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformic acid, diazenediacetic acid, phenyldiazenediformic acid, diphenyldiazenediformic acid, phenyldiazenediacetic acid, and diphenyldiazenediacetic acid.

N-O Valence Stabilizer #34: Examples of diazenediformaldehydes, diazenediacetaldehydes, bis(diazenediformaldehydes), bis(diazenediacetaldehydes), poly(diazenediformaldehydes), and

poly(diazenediactaldehydes) (N-O Tridentates and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: diazenediformaldehyde, diazenediactaldehyde, diphenyldiazenediformaldehyde, and diphenyldiazenediactaldehyde.

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N-O Valence Stabilizer #35: Examples of ortho-hydroxy (or -carboxy) substituted formazans, bis(o-hydroxy or -carboxy substituted formazans), and poly(o-hydroxy or -carboxy substituted formazans) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 1-(2-hydroxyphenyl)-3,5-diphenylformazan; 1-(2-methoxyphenyl)-3,5-diphenylformazan; 1,5-bis(2-hydroxyphenyl)-3-phenylformazan; and 5-bis(2-methoxyphenyl)-3-phenylformazan.

N-O Valence Stabilizer #36: Examples of ortho-hydroxy (or -carboxy) substituted azines (including ketazines), bis(o-hydroxy or carboxy substituted azines), and poly(o-hydroxy or carboxy substituted azines) (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxy-1-benzalazine; 2-hydroxy-1-naphthalazine; and 2-hydroxy-1-cyclohexanonazine.

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N-O Valence Stabilizer #37: Examples of Schiff Bases with one Imine ($C=N$) Group and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Bidentates, N-O Tridentates, N-O Tetracentates, N-O Pentadentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N-(Salicylaldehyde)isopropylamine; N-(2-Furfural)isopropylamine; N-(2-Acetyl furano)isopropylamine; N-(2-Hydroxyacetophenono)isopropylamine; N-(Pyridoxalo)isopropylamine; N-(Salicylaldehyde)cyclohexylamine; N-(2-Furfural)cyclohexylamine; N-(2-Acetyl furano)cyclohexylamine; N-(2-Hydroxyacetophenono)cyclohexylamine; N-(Pyridoxalo)cyclohexylamine; N-(Salicylaldehyde)aniline; N-(2-Furfural)aniline (Stenhauz salt); N-(2-Acetyl furano)aniline; N-(2-Hydroxyacetophenono)aniline; N-(Pyridoxalo)aniline; N-(Salicylaldehyde)aminonorborene;

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- N-(2-Furfuralo)aminonorbornane; N-(2-Acetylfurano)aminonorbornane; N-(2-Hydroxyacetophenono)aminonorbornane; N-(Pyridoxalo)aminonorbornane; (Salicylaldehydo)anisidine; 2-salicylideneiminobenzothiazole; (Salicylaldehydo)sulfamethazine; N'-histidine-3-methoxysalicylidenimine (V-his); N-(o-carboxybenzaldehydo)-2-aminophenol;
- 5 N-(salicylaldehydo)isatin; N-(2-furfuralo)isatin; N-(2-acetylfurano)isatin; N-(pyridoxalo)isatin; N-(2-hydroxyacetophenono)isatin; hydrofuramide; 2-furancarboxaldehyde phenylhydrazone; 2-furancarboxaldehyde 2-pyridyl hydrazone; salicylaldehyde phenylhydrazone; and salicylaldehyde 2-pyridyl hydrazone. Also includes hydrazones with ortho-O substitution.
- 10 N-O Valence Stabilizer #38: Examples of Schiff Bases with two Imine (C=N) Groups and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Tridentates, N-O Tetradentates, N-O Pentadentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-(2,5-Furandicarboxaldehydo)diisopropylamine; N,N'-(2,5-
- 15 Furandicarboxaldehydo)dicyclohexylamine; N,N'-(2,5-Furandicarboxaldehydo)dianiline; N,N'-(2,5-Furandicarboxaldehydo)di-aminonorbornane; N,N'-(o-Hydroxyphthalicdialdehydo)diisopropylamine; N,N'-(o-Hydroxyphthalicdialdehydo)dicyclohexylamine; N,N'-(o-Hydroxyphthalicdialdehydo)dianiline; N,N'-(o-Hydroxyphthalicdialdehydo)di-aminonorbornane; N,N'-(o-
- 20 Hydroxyformylcamphoro)diisopropylamine; N,N'-(o-Hydroxyformylcamphoro)dicyclohexylamine; N,N'-(o-Hydroxyformylcamphoro)dianiline; N,N'-(o-Hydroxyformylcamphoro)di-aminonorbornane; N,N'-(o-Hydroxydiacetylbenzeno)diisopropylamine; N,N'-(o-Hydroxydiacetylbenzeno)dicyclohexylamine; N,N'-(o-Hydroxydiacetylbenzeno)dianiline; N,N'-(o-Hydroxydiacetylbenzeno)di-aminonorbornane; N,N'-(3,6-Dihydroxy-1,2-
- 25 cyclohexanono)diisopropylamine; N,N'-(3,6-Dihydroxy-1,2-cyclohexanono)dicyclohexylamine; N,N'-(3,6-Dihydroxy-1,2-cyclohexanono)dianiline; N,N'-(3,6-Dihydroxy-1,2-cyclohexanono)di-aminonorbornane; N,N'-(2,5-Diacetylfurano)diisopropylamine; N,N'-(2,5-Diacetylfurano)dicyclohexylamine; N,N'-(2,5-Diacetylfurano)dianiline; N,N'-(2,5-
- 30 Diacetylfurano)di-aminonorbornane; N,N'-(Salicylaldehydo)ethylenediamine; N,N'-(o-Hydroxynaphthaldehydo)ethylenediamine; N,N'-(o-Hydroxyacetophenono)ethylenediamine; ;

- N,N'-(Salicylaldehydo)trimethylenediamine; N,N'-(o-Hydroxynaphthaldehydo)trimethylenediamine; N,N'-(o-Hydroxyacetophenono)trimethylenediamine; ; N,N'-(Salicylaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Hydroxynaphthaldehydo)cyclohexane-1,2-diamine; N,N'-(o-Hydroxyacetophenono)cyclohexane-1,2-diamine; N,N'-(Salicylaldehydo)-1,2-diaminobenzene; N,N'-(o-Hydroxynaphthaldehydo)-1,2-diaminobenzene; N,N'-(o-Hydroxyacetophenono)-1,2-diaminobenzene; N,N'-bis(salicylaldehydo)-1,12-diaminododecane (Saldn); N,N'-bis(3-methoxysalicylaldehydo)-o-phenyldiamine; N,N'-bis(3,4-difluorobenzaldehydo)-4,4'-benzidine; and N,N'-phenylenebis(3-methoxysalicylidenimine) (V-ph-V). Also includes hydrazones with
- 10 ortho-O substitution.

- N-O Valence Stabilizer #39: Examples of Schiff Bases with three Imine (C=N) Groups and with ortho- or alpha- or beta-hydroxy or carboxy or carbonyl substitution (N-O Tetridentates, N-O Pentadentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence
- 15 stabilizers for Ce^{+4} include, but are not limited to: N,N',N''-(Salicylaldehydo)tris(2-aminoethyl)amine; N,N',N''-(o-Hydroxynaphthaldehydo)tris(2-aminoethyl)amine; and N,N',N''-(o-Hydroxyacetophenono)tris(2-aminoethyl)amine. Also includes hydrazones with ortho-O substitution.

- 20 N-O Valence Stabilizer #40: Examples of silylaminoalcohols (N-O Bidentates, N-O Tridentates, N-O Tetridentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: silatranes.

- N-O Valence Stabilizer #41: Examples of hydroxyalkyl imines (imino alcohols) (N-O
- 25 Bidentates, N-O Tridentates, N-O Tetridentates, and N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxycyclohexylimine; 3-hydroxy-2-iminonorbornane; 2,2'-diiminodicyclohexyl ether; oxamide; 3-imino-1,5-pentanedialdehyde; iminodiacetic acid; and iminodipropionic acid.

- 30 N-O Valence Stabilizer #42: Examples of hydroxyaryl amines and hydroxyaryl imines (N-O Bidentates, N-O Tridentates, N-O Tetridentates, and N-O Hexadentates) that meet the

requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminophenol; 2-aminobenzoic acid (anthranilic acid); 2-aminoaniline; o-phenetidine; o-anisidine; 2-hydroxymethyl)-alpha-aminotoluene; 1-amino-2-naphthol; 2-amino-1-naphthol; 2,2'-di(aminomethyl)diphenylketone; isophoronediamine; tris-2,4,6-dimethylaminomethyl phenol; di(2-amino)phenyl ether; 1,3-di(2-amino)phenyl-2-hydroxypropane; 1,3-di(3-amino)phenyl-2-hydroxypropane; 1,3-di(2-hydroxy)phenyl-2-aminopropane; 1,3-di(3-hydroxy)phenyl-2-aminopropane; 2,2'-dihydroxyiminodibenzyl; 2,2'-iminodibenzoic acid; 2,2'-dihydroxyiminostilbene; poly(o-phenetidine); poly(o-aminophenol); poly(o-anisidine); and 3-(anilino)propionamide.

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N-O Valence Stabilizer #43: Examples of five-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional oxygen atom binding site not in a ring (N-O Bidentates, N-O Tridentates, N-O Tetridentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 15 2-hydroxypyrrole; 2-(methylhydroxy)methylpyrrole; 2,5-(hydroxymethyl)pyrrole; 2,5-(methylhydroxymethyl)pyrrole; imidazoline-2-one (2-hydroxyimidazole); 2-hydroxythiazoline; 2-hydroxybenzimidazole; 2-hydroxybenzothiazole; 2-hydroxybenzoxazole; 2-hydantoin; di-2-pyridylglyoxal (2,2'-pyridil); bis((1-pyrazolyl)methane)ether; bis(2-(1-pyrazolyl)ethane)ether; bis(benzimidazolylmethane)ether; bis(benzimidazolylethane)ether; tris(imidazolyl)methanol;
- 20 tris(imidazolylmethane)methanol; N-hydroxymethyl-N,N-(benzimidazolylmethane)amine; N-(2-hydroxyethyl)-N,N-(benzimidazolylmethane)amine; N,N'-di(benzimidazolylmethane)-1,3-diamino-2-hydroxypropane; N,N,N',N'-tetrakis(benzimidazolylmethane)-1,3-diamino-2-hydroxypropane; bis(N,N-((4-imidazolyl)methane)2-aminoethane)ether; 4-carboxybenzotriazole; antipyrine; 4-aminoantipyrine (aap); hydantoin; aminoalkylhydantoins; 2,5-oxazolidinedione;
- 25 benzyldibenzoyltriazole (bdbt); 5-hydroxymethylimidazole; dicarboxyalkylbenzotriazoles; bis(hydroxyphenyl)aminotriazoles; pyrrole-2-carboxaldehyde; (oxopyrrolidinylalkyl)triazoles; alkoxybenzotriazoles; aryloxybenzotriazoles; 3-salicylamido-4,5-dihydro-1,2,4-triazole; 5-(alkoxy)benzotriazole; (polyoxyalkylene)oxazolidines; 1-(dialkylaminomethyl)-5-carboxyalkylbenzotriazole; 1-(2-hydroxyethyl)imidazoline; 1-acetoxyimidazole; 1-
- 30 acetylimidazole; benzotriazolecarboxylic acid; poly(oxyalkylated)pyrazoles; poly(oxyalkylated)thiadiazoles; 1,2,4-triazole-3-carboxylic acid; 5-hydroxypyrazole; 3-phenyl-

1,2,4-triazol-5-one (ptr); 1-acetylbenzimidazole; 1-[(acetoxy)ethyl]benzimidazole; creatinine; indole-2-carboxylic acid; pyrrole-2-carboxylic acid; imidazole-2-carboxylic acid; pyrazole-2-carboxylic acid; and 1,1'-oxalyldiimidazole.

- 5 N-O Valence Stabilizer #44: Examples of six-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional oxygen atom binding site not in a ring (N-O Bidentates, N-O Tridentates, N-O Tetridentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-aminomethyl-3-pyridinemethanol (including pyridoxamine); 2-hydroxypyridine; 2-
- 10 (methylhydroxy)methylpyridine; 2-(2-(methylhydroxy)ethyl)pyridine; 2,6-(hydroxymethyl)pyridine; 2,6-(methylhydroxymethyl)pyridine; 2-hydroxypyrimidine; 2-dihydroxymethylpyrimidine; 2-hydroxyquinoline; 8-hydroxyquinoline (oxine); 8-methylhydroxyquinoline; 2-hydroxyquinazoline; orotic acid (1,2,3,6-tetrahydro-2,6-dioxo-4-pyrimidinecarboxylic acid) (6-uracilcarboxylic acid); 1-methylpyrimidine-2-one; uracil; 6-
- 15 hydroxypurine; bis(N,N,N',N'-tetra(2-(2-pyridyl)ethane)aminomethane)ether; bis(N,N,N',N'-tetra(2-(2-pyridyl)ethane)aminoethane)ether; quinazol-4-one; quinazol-2-one; 5-azathymine; 2-hydroxybenzimidazole (2-hbz); guanine; 1,3,5-triazin-6-one; 6-hydroxy-1,3,5-triazine; 4,6-dihydroxy-1,3,5-triazine; triazine carboxylic acids; 2,3-dihydroxypyridine; thiomorpholin-3-one; hydroxytetrahydropyrimidines; 2-piperazinones; 2-piperidinones; dilituric acid; actinoquinol;
- 20 caffeine; citrazinic acid; picolinic acid; 2-quinolol; 2,6-dimethoxypyridine; quinoxaline-2-carboxylic acid; flucytosine; hypoxanthine; hexamethylmelamine; hydroorotic acid; isoorotic acid; xanthine; leucopterin; nitroorotic acid; 8-azaguanine; and cyanuric acid.

- N-O Valence Stabilizer #45: Examples of five-membered heterocyclic rings containing one or
- 25 two oxygen atoms and having at least one additional nitrogen atom binding site not in a ring (N-O Bidentates, N-O Tridentates, N-O Tetridentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminofuran; 2,5-diaminofuran; 2-aminomethylfuran; 2,5-di(aminomethyl)furan; 2-aminobenzofuran; and 2-amino-1,3-dioxolane.

N-O Valence Stabilizer #46: Examples of six-membered heterocyclic rings containing one or two oxygen atoms and having at least one additional nitrogen atom binding site not in a ring (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 5 2-aminopyran; 2,6-diaminopyran; 2-aminomethylpyran; 2,6-di(aminomethyl)pyran; and 2-aminobenzopyran.

N-O Valence Stabilizer #47: Examples of five-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional oxygen atom binding site in a separate ring (N-O Bidentates, N-O Tridentates, N-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-furan)pyrrole; 2,5-di(2-furan)pyrrole; 2-(2-pyran)pyrrole; 2,5-di(2-pyran)pyrrole; 2,5-di(2-pyrrole)furan; and 2,6-di(2-pyrrole)pyran.

- 15 N-O Valence Stabilizer #48: Examples of six-membered heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional oxygen atom binding site in a separate ring (N-O Bidentates, N-O Tridentates, N-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-furan)pyridine; 2,6-di(2-furan)pyridine; 2-(2-pyran)pyridine; 2,6-di(2-pyran)pyridine; 2,5-di(2-pyridyl)furan; 2,6-di(2-pyridyl)pyran; and drometrizole.

- N-O Valence Stabilizer #49: Examples of two-, three-, four-, six-, eight-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) or oxygen (usually hydroxy, carboxy, or carbonyl groups) and are not contained in component heterocyclic rings (N-O Bidentates, N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: azaoxacyclobutane ([4]aneNO); azaoxacyclopentane ([5]aneNO); azaoxacyclohexane ([6]aneNO); azaoxacycloheptane ([7]aneNO); azaoxacyclooctane ([8]aneNO); azaoxacyclobutene ([4]eneNO); azaoxacyclopentene ([5]eneNO); azaoxacyclohexene ([6]eneNO); azaoxacycloheptene ([7]eneNO); azaoxacyclooctene
- 25
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- ([8]eneNO); azaoxacyclobutadiene ([4]dieneNO); azaoxacyclopentadiene ([5]dieneNO); azaoxacyclohexadiene ([6]dieneNO); azaoxacycloheptadiene ([7]dieneNO); azaoxacyclooctadiene ([8]dieneNO); diazaoxacyclohexane ([6]aneON₂); diazaoxacycloheptane ([7]aneON₂); diazaoxacyclooctane ([8]aneON₂); diazaoxacyclononane ([9]aneON₂);
- 5 diazaoxacyclodecane ([10]aneON₂); diazaoxacycloundecane ([11]aneON₂); diazaoxacyclododecane ([12]aneON₂); diazaoxacyclohexene ([6]eneON₂); diazaoxacycloheptene ([7]eneON₂); diazaoxacyclooctene ([8]eneON₂); diazaoxacyclononene ([9]eneON₂); diazaoxacyclodecene ([10]eneON₂); diazaoxacycloundecene ([11]eneON₂); diazaoxacyclododecene ([12]eneON₂); diazadioxacyclooctane ([8]aneO₂N₂);
- 10 diazadioxacyclononane ([9]aneO₂N₂); diazadioxacyclodecane ([10]aneO₂N₂); diazadioxacycloundecane ([11]aneO₂N₂); diazadioxacyclododecane ([12]aneO₂N₂); diazadioxacyclotridecane ([13]aneO₂N₂); diazadioxacyclotetradecane ([14]aneO₂N₂); diazadioxacyclopentadecane ([15]aneO₂N₂); diazadioxacyclohexadecane ([16]aneO₂N₂); diazadioxacycloheptadecane ([17]aneO₂N₂); diazadioxacyclooctadecane ([18]aneO₂N₂);
- 15 diazadioxacyclononadecane ([19]aneO₂N₂); diazadioxacycloeicosane ([20]aneO₂N₂); diazadioxacyclooctadiene ([8]dieneO₂N₂); diazadioxacyclononadiene ([9]dieneO₂N₂); diazadioxacyclodecadiene ([10]dieneO₂N₂); diazadioxacycloundecadiene ([11]dieneO₂N₂); diazadioxacyclododecadiene ([12]dieneO₂N₂); diazadioxacyclotridecadiene ([13]dieneO₂N₂); diazadioxacyclotetradecadiene ([14]dieneO₂N₂); diazadioxacyclopentadecadiene
- 20 ([15]dieneO₂N₂); diazadioxacyclohexadecadiene ([16]dieneO₂N₂); diazadioxacycloheptadecadiene ([17]dieneO₂N₂); diazadioxacyclooctadecadiene ([18]dieneO₂N₂); diazadioxacyclononadecadiene ([19]dieneO₂N₂); and diazadioxacycloeicosadiene ([20]dieneO₂N₂).
- 25 N-O Valence Stabilizer #50: Examples of four-, six-, eight-, or ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or oxygen and are contained in component heterocyclic rings (N-O Bidentates, N-O Tridentates, N-O Tetridentates, or N-O Hexadentates) that meet the requirements for use as “wide band” valence stabilizers for Ce⁺⁴
- 30 include, but are not limited to: dipyrandipyridines; difurandipyrroles; tripyrantripyrindines; trifurantripyrroles; tetrapyrantetrapyrindines; and tetrafurantetrapyrroles.

- N-O Valence Stabilizer #51: Examples of four-, six-, eight-, or ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or oxygen and are contained in a combination of heterocyclic rings and amine, imine, hydroxy, carboxy, or carbonyl groups (N-
- 5 O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: azaoxatetraphyrins; diazadioxatetraphyrins; azaoxahexaphyrins; diazadioxahexaphyrins; and triazatrioxahexaphyrins.
- 10 S-O Valence Stabilizer #1: Examples of 1,3-monothioketones (monothio-beta-ketonates), 1,3,5-monothioketones, 1,3,5-dithioketones, bis(1,3-monothioketones), and poly(1,3-monothioketones) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: hexafluoropenta-2-thione-4-ketone; 1,3-diphenyl-1,3-propana-1-thione-3-ketone;
- 15 benzoylthiopinacolone; cyclohexoylthiocyclohexoxymethane; diphenylpentanedithionate; tetramethylnonanedithionate; hexafluoroheptanedithionate; trifluoroheptanedithionate; 1-(2-thienyl)-butan-1-thione-3-ketone, 1-(2-naphthyl)-butan-1-thione-3-ketone, and trifluoroacetylthiocamphor.
- 20 S-O Valence Stabilizer #2: Examples of thiomalonamides (thiomalonodiamides), bis(thiomalonamides), and polythiomalonamides (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: thiomalonamide, N-phenylthiomalonamide, N-benzylthiomalonamide, N-pentafluorophenylthiomalonamide, N-cyclohexylthiomalonamide, N-
- 25 norbornylthiomalonamide, N,N'-diphenylthiomalonamide, N,N'-dibenzylthiomalonamide, N,N'-dipentafluorophenylthiomalonamide, N,N'-dicyclohexylthiomalonamide, and N,N'-norbornylthiomalonamide.

- S-O Valence Stabilizer #3: Examples of 2-thioacylacetamides, 2-acylthioacetamides, bis(2-
- 30 thioacylacetamides), bis(2acylthioacetamides), poly(2-thioacylacetamides), and poly(2-Acylthioacetamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the

requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-acetothioacetamide, 2-thioacetoacetamide, N-phenyl-2-acetothioacetamide, N-pentafluorophenyl-2-acetothioacetamide, N-benzyl-2-acetothioacetamide, N-cyclohexyl-2-acetothioacetamide, N-norbornyl-2-acetothioacetamide, N-phenyl-2-benzothioacetamide, N-pentafluorophenyl-2-pentafluorobenzothioacetamide, and N-cyclohexyl-2-cyclohexothioacetamide.

S-O Valence Stabilizer #4: Examples of dithiodicarbonyl diamides, bis(dithiodicarbonyl diamides), and poly(dithiodicarbonyl diamides) (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodicarbonyl diamide; N-phenyldithiodicarbonyl diamide; N-pentafluorophenyldithiodicarbonyl diamide; N-benzoyldithiodicarbonyl diamide; N-cyclohexyldithiodicarbonyl diamide; N-norbornyldithiodicarbonyl diamide; N,N'-diphenyldithiodicarbonyl diamide; N,N'-dipentafluorophenyldithiodicarbonyl diamide; N,N'-dibenzoyldithiodicarbonyl diamide; N,N'-dicyclohexyldithiodicarbonyl diamide; and N,N'-dinorbornyldithiodicarbonyl diamide.

S-O Valence Stabilizer #5: Examples of monothiohypophosphoric acids, bis(monothiohypophosphoric acids), poly(monothiohypophosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiohypophosphoric acid, methylmonothiohypophosphoric acid, isopropylmonothiohypophosphoric acid, tert-butylmonothiohypophosphoric acid, phenylmonothiohypophosphoric acid, pentafluorophenylmonothiohypophosphoric acid, benzylmonothiohypophosphoric acid, cyclohexylmonothiohypophosphoric acid, norbornylmonothiohypophosphoric acid, dimethylmonothiohypophosphoric acid, diisopropylmonothiohypophosphoric acid, di-tert-butylmonothiohypophosphoric acid, diphenylmonothiohypophosphoric acid, di-pentafluorophenylmonothiohypophosphoric acid, dibenzylmonothiohypophosphoric acid, dicyclohexylmonothiohypophosphoric acid, and dinorbornylmonothiohypophosphoric acid.

S-O Valence Stabilizer #6: Examples of monothiohypophosphoramides,

bis(monothiohypophosphoramides), and poly(monothiohypophosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiohypophosphoramide, N-

- 5 methylmonothiohypophosphoramide, N-isopropylmonothiohypophosphoramide, N-tert-butylmonothiohypophosphoramide, N-phenylmonothiohypophosphoramide, N-pentafluorophenylmonothiohypophosphoramide, N-benzylmonothiohypophosphoramide, N-cyclohexylmonothiohypophosphoramide, N-norbornylmonothiohypophosphoramide, N,N”-dimethylmonothiohypophosphoramide, N,N”-diisopropylmonothiohypophosphoramide, N,N”-di-tert-butylmonothiohypophosphoramide, N,N”-diphenylmonothiohypophosphoramide, N,N”-di-pentafluorophenylmonothiohypophosphoramide, N,N”-dibenzylmonothiohypophosphoramide, N,N”-dicyclohexylmonothiohypophosphoramide, and N,N”-dinorbornylmonothiohypophosphoramide.

15 S-O Valence Stabilizer #7: Examples of monothioimidodiphosphoric acids,

monothiohydrazidodiphosphoric acids, bis(monothioimidodiphosphoric acids), bis(monothiohydrazidodiphosphoric acids), poly(monothioimidodiphosphoric acids), poly(monothiohydrazidodiphosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence

- 20 stabilizers for Ce^{+4} include, but are not limited to: monothioimidodiphosphoric acid, methylmonothioimidodiphosphoric acid, isopropylmonothioimidodiphosphoric acid, tert-butylmonothioimidodiphosphoric acid, phenylmonothioimidodiphosphoric acid, pentafluorophenylmonothioimidodiphosphoric acid, benzylmonothioimidodiphosphoric acid, cyclohexylmonothioimidodiphosphoric acid, norbornylmonothioimidodiphosphoric acid, 25 dimethylmonothioimidodiphosphoric acid, diisopropylmonothioimidodiphosphoric acid, di-tert-butylmonothioimidodiphosphoric acid, diphenylmonothioimidodiphosphoric acid, di-pentafluorophenylmonothioimidodiphosphoric acid, dibenzylmonothioimidodiphosphoric acid, dicyclohexylmonothioimidodiphosphoric acid, and dinorbornylmonothioimidodiphosphoric acid.

30 S-O Valence Stabilizer #8: Examples of monothioimidodiphosphoramides,

monothiohydrazidodiphosphoramides, bis(monothioimidodiphosphoramides),

bis(monothiohydrazidodiphosphoramides), poly(monothioimidodiphosphoramides), and poly(monothiohydrazidodiphosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioimidodiphosphoramide, N-

- 5 methylmonothioimidodiphosphoramide, N-isopropylmonothioimidodiphosphoramide, N-tert-butylmonothioimidodiphosphoramide, N-phenylmonothioimidodiphosphoramide, N-pentafluorophenylmonothioimidodiphosphoramide, N-benzylmonothioimidodiphosphoramide, N-cyclohexylmonothioimidodiphosphoramide, N-norbornylmonothioimidodiphosphoramide, N,N”-dimethylmonothioimidodiphosphoramide, N,N”-diisopropylmonothioimidodiphosphoramide, N,N”-di-tert-butylmonothioimidodiphosphoramide, N,N”-diphenylmonothioimidodiphosphoramide, N,N”-di-pentafluorophenylmonothioimidodiphosphoramide, N,N”-dibenzylmonothioimidodiphosphoramide, N,N”-dicyclohexylmonothioimidodiphosphoramide, and N,N”-dinorbornylmonothioimidodiphosphoramide.

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S-O Valence Stabilizer #9: Examples of monothiodiphosphoramides, bis(monothiodiphosphoramides), and poly(monothiodiphosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiodiphosphoramide, N-

- 20 methylmonothiodiphosphoramide, N-isopropylmonothiodiphosphoramide, N-tert-butylmonothiodiphosphoramide, N-phenylmonothiodiphosphoramide, N-pentafluorophenylmonothiodiphosphoramide, N-benzylmonothiodiphosphoramide, N-cyclohexylmonothiodiphosphoramide, N-norbornylmonothiodiphosphoramide, N,N”-dimethylmonothiodiphosphoramide, N,N”-diisopropylmonothiodiphosphoramide, N,N”-di-tert-butylmonothiodiphosphoramide, N,N”-diphenylmonothiodiphosphoramide, N,N”-di-pentafluorophenylmonothiodiphosphoramide, N,N”-dibenzylmonothiodiphosphoramide, N,N”-dicyclohexylmonothiodiphosphoramide, and N,N”-dinorbornylmonothiodiphosphoramide.

S-O Valence Stabilizer #10: Examples of monothiodiphosphoric acids,

- 30 bis(monothiodiphosphoric acids), poly(monothiodiphosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “wide

band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiodiphosphoric acid, methylmonothiodiphosphoric acid, isopropylmonothiodiphosphoric acid, tert-butylmonothiodiphosphoric acid, phenylmonothiodiphosphoric acid, pentafluorophenylmonothiodiphosphoric acid, benzylmonothiodiphosphoric acid, cyclohexylmonothiodiphosphoric acid, norbornylmonothiodiphosphoric acid, dimethylmonothiodiphosphoric acid, diisopropylmonothiodiphosphoric acid, di-tert-butylmonothiodiphosphoric acid, diphenylmonothiodiphosphoric acid, di-pentafluorophenylmonothiodiphosphoric acid, dibenzylmonothiodiphosphoric acid, dicyclohexylmonothiodiphosphoric acid, and dinorbornylmonothiodiphosphoric acid.

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S-O Valence Stabilizer #11: Examples of monothiocarbamates, bis(monothiocarbamates), and poly(monothiocarbamates) (including N-hydroxymonothiocarbamates and N-mercaptomonothiocarbamates) (S-O Bidentates, S-O Tridentates, and S-O Tetridentates) that meet the requirements for use as “wide band” valence stabilizers for Ce^{+4} include, but are not

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limited to: dimethylmonothiocarbamate (dmmtc); di(trifluorodimethyl)monothiocarbamate; diethylmonothiocarbamate (demtc); dipropylmonothiocarbamate; diisopropylmonothiocarbamate; dibutylmonothiocarbamate; ditertbutylmonothiocarbamate; dicyanamidomonothiocarbamate; diphenylmonothiocarbamate; di(pentafluorophenyl)monothiocarbamate; dibenzylmonothiocarbamate;

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dinaphthylmonothiocarbamate; dicyclohexylmonothiocarbamate; dinorbornylmonothiocarbamate; diadamantylmonothiocarbamate; pyrrolidinomonothiocarbamate (pyrmtc); piperidinomonothiocarbamate (pipmtc); morpholinomonothiocarbamate (mormtc); thiamorpholinomonothiocarbamate; 3-pyrrolinomonothiocarbamate; pyrrolomonothiocarbamate; oxazolomonothiocarbamate;

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isoxazolomonothiocarbamate; thiazolomonothiocarbamate; isothiazolomonothiocarbamate; indolomonothiocarbamate; carbazolomonothiocarbamate; pyrazolinomonothiocarbamate; imidazolinomonothiocarbamate; pyrazolomonothiocarbamate; imidazolomonothiocarbamate; indazolomonothiocarbamate; and triazolomonothiocarbamate.

Water-soluble precursors for the organic valence stabilizers are typically used to ensure that sufficient material is available for deposition from aqueous solutions. Identification of suitable water soluble precursors can be difficult because many of these organics do not form a wide range of water-soluble compounds.

5 As with the inorganic valence stabilizers, crosses between two or more organic valence stabilizers can be used to stabilize Ce^{+4} for corrosion protection. For example, in some instances it may be desirable to form a valence stabilizer out of a beta-diketone and an amine ligand. Both of these materials can complex to form a mixed beta-diketone/amine valence stabilizer out of the rinsing or sealing solution during the coating process.

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2c) Narrow Band Inorganic Valence Stabilizers for Tetravalent Cerium

Narrow band valence stabilizers can be used to stabilize Ce^{+4} for corrosion protection, but they are less typical. Narrow band valence stabilizers exhibit some limitation in their use when compared to wide band stabilizers. They may be toxic or may complex Ce^{+4} only with difficulty.

15 These narrow band stabilizers include, but are not limited to, bismuthates, germanates, arsenates, titanates, zirconates, and selenates. For example, valence stabilizers using arsenate are less desirable because their inherent toxicity is very large (greater than Cr^{+6}), although they may be very effective at inhibiting corrosion when used with Ce^{+4} . Arsenates can be used as valence stabilizers for Ce^{+4} when the toxicity of the rinse or sealing solution is not a factor in its use.

20 Other narrow band stabilizers may result in Ce^{+4} -stabilizer complexes with limited stability, an undesirable solubility range, or limited electrostatic characteristics, and they would be useful only in limited applications. Formation of a protective shell of octahedra or icosahedra with borates (B^{+3}), aluminates (Al^{+3}), and silicates (Si^{+4}) around the Ce^{+4} ion is difficult but possible. These compounds are known to form octahedra or icosahedra, but tend to polymerize
25 in chain-like structures when precipitated from aqueous solution under ambient conditions.

These and other narrow band stabilizers can provide some degree of corrosion protection when complexed with Ce^{+4} , but will not necessarily perform with the same efficiency as the wide band stabilizers by themselves. Combinations of these materials, such as phosphosilicates, aluminosilicates, or borosilicates may also function as narrow band inorganic valence stabilizers.

30 Narrow band inorganic stabilizers used in combination with wide band inorganic stabilizers described above can be used to provide significant corrosion protection. Conversely,

modifications of wide band inorganic valence stabilizers can result in a complex with reduced corrosion inhibition. For example, heteropolymetallates can contain ions in addition to the desired Ce^{+4} ion.

5 The central cavity of the heteropolymetallates can contain ions in addition to the desired Ce^{+4} ion. For example, the use of silicomolybdates, phosphomolybdates, silicotungstates, and phosphotungstates is possible. In these Ce^{+4} -valence stabilizer complexes, Si^{+4} or P^{+5} ions also occupy the central cavity of the complex with the Ce^{+4} ion. The inclusion of additional ions in the central cavity reduces the stability of the complex, and thereby leads to lower corrosion protection. Nonetheless, these complexes also demonstrated some corrosion-inhibiting activity.

10 The additional ions that can be included within the central cavity of the heteropolymetallates described above depend upon the size of the central cavity, which in turn depends upon the specific chemistry exhibited by an inorganic valence stabilizer (e.g., molybdate, tungstate, periodate, carbonate, etc.). In general, these additional ions must also be small so as to ensure the stability of the formed Ce^{+4} -valence stabilized complex. Examples of
15 small additional ions include, but are not limited to: B^{+3} , Al^{+3} , Si^{+4} , P^{+5} , Ti^{+4} , V^{+5} , V^{+4} , Cr^{+6} , Cr^{+4} , Cr^{+3} , Mn^{+4} , Mn^{+3} , Mn^{+2} , Co^{+2} , Co^{+3} , Fe^{+3} , Fe^{+2} , Ni^{+2} , Ni^{+3} , Ni^{+4} , Cu^{+2} , Cu^{+3} , Zn^{+2} , Ga^{+3} , Ge^{+4} , As^{+5} , As^{+3} , and Zr^{+4} .

Water-soluble precursors for these materials are desirable. Typically, the free acids (e.g., silicomolybdic acid, phosphotungstic acid, borotungstic acid, etc.) offer the most water-soluble
20 precursors for these materials.

2d) Narrow Band Organic Valence Stabilizers for Tetravalent Cerium

Narrow band organic valence stabilizers include those general classes of chemical compounds that result in Ce^{+4} -valence stabilizer complexes that are either less stable, more
25 soluble in water, or more toxic than the wide band organic stabilizers. As discussed above, the properties of a particular Ce^{+4} -containing complex can be altered by changing the substituent groups on these general classes of valence stabilizers. This can influence the effectiveness of corrosion inhibition normally achieved using that specific complex.

Table 3. Narrow Band Organic Valence Stabilizers for the Ce⁺⁴ Ion

General Structural Name (Type of Organic)	Structural Representation
<u>N Valence Stabilizer #1:</u> Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) and are not contained in Component Heterocyclic Rings (N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)	Macrocyclic ligands containing five, seven, or nine nitrogen binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #2:</u> Five-, or Seven-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in Component 5-Membered Heterocyclic Rings (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing a total of five or seven five-membered heterocyclic rings containing nitrogen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #3:</u> Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in a Combination of 5-Membered Heterocyclic Rings and Amine or Imine Groups (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide nitrogen binding sites to valence stabilize the central metal ion. Other amine or imine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is five, seven, or nine. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #4:</u> Five- or Seven-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in Component 6-Membered Heterocyclic Rings (N-N	Macrocyclic ligands containing a total of five or seven six-membered heterocyclic rings containing nitrogen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen

Tridentates, N-N Tetradentates, or N-N Hexadentates)	or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #5:</u> Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen and are contained in a Combination of 6-Membered Heterocyclic Rings and Amine or Imine Groups (N-N Tridentates, N-N Tetradentates, or N-N Hexadentates)	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These heterocyclic rings provide nitrogen binding sites to valence stabilize the central metal ion. Other amine or imine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is five, seven, or nine. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N Valence Stabilizer #6:</u> Silylamines and Silazanes, including Macrocyclic Derivatives, wherein at least one Nitrogen Atom is a Binding Site (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)	$N(SiR_3)_3$, $R'N(SiR_3)_2$, or $R'R''N(SiR_3)$ for silylamines; and $[RR''Si-NR']_x$ ($x = 1-10$) for silazanes where R, R', and R'' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>N Valence Stabilizer #7:</u> Guanidines, Diguandines, and Polyguanidines (N-N Bidentates, N-N Tridentates, N-N Tetradentates, and N-N Hexadentates)	$RR'-N-C(=NH)NR''R'''$, where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #8:</u> Phosphonitrile Amides, and Bis(phosphonitrile amides) (N-N Bidentates, N-N Tetradentates)	$RR'-N-P(=N)-N-R''R'''$, where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #9:</u> Phosphonimidic Diamides, Bis(Phosphonimidic Diamides), and Poly(Phosphonimidic Diamides) (N-N Bidentates, N-N Tetradentates)	$(NH=)PR''''(-NRR')(-NR''R''')$, where R, R', R'', R''', and R'''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or

	P atoms.
<u>N Valence Stabilizer #10:</u> Phosphonamidimidic Acid, Phosphonamidimidothioic Acid, Bis(Phosphonamidimidic Acid), Bis(Phosphonamidimidothioic Acid), Poly(Phosphonamidimidic Acid), Poly(Phosphonamidimidothioic Acid), and derivatives thereof (N-N Bidentates, and N-N Tetradentates)	(NH=)PR'''(-NRR')(-OR'') for phosphonamidimidic acid and (NH=)PR'''(-NRR')(-SR'') for phosphonamidimidothioic acid, where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #11:</u> Pyridinaldimines, Bis(pyridinaldimines), and Poly(pyridinaldimines) (N-N Bidentates, N-N Tridentates, and N-N Tetradentates)	C ₅ H ₅ N-CR=NR', where C ₅ H ₅ N is a pyridine derivative, R is typically an aromatic constituent (i.e., -C ₆ H ₅), and R' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #12:</u> Hydrazones, Bis(hydrazones), and Poly(hydrazones) (N Monodentates, N-N Bidentates, N-N Tridentates, and N-N Tetradentates)	R-NH-N=R', where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Either R or R' is typically an aryl group.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #13:</u> Azo compounds including triazenes without chelate substitution at the ortho- (for aryl) or alpha- or beta- (for alkyl) positions, Bis(azo compounds), or Poly(azo compounds) (N Monodentates, N-N Bidentates, or N-N-N Tridentates)	R-N=N-R' for azo compounds, R-N=N-NH-R' for triazenes, where R, and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho- chelate substituted aryl azo compounds, and alpha- or beta-substituted alkyl azo compounds.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #14:</u> Formazans, Bis(formazans), and Poly(formazans) without ortho- hydroxy, carboxy, thiol, mercapto, amino, or hydrazido substitution (N-N Bidentates, N-N Tetradentates, and N-N Hexadentates)	R-N=N-CR'=N-NR''R''', where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho- hydroxy, carboxy, thiol,

	mercapto, amino, or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #15:</u> Hydramides (N-N Bidentates)	$R-CH=N-CHR'-N=CHR''$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (R, R', and R'' are typically aryl derivatives.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #16:</u> Azines (including ketazines), Bis(azines), and Poly(azines) without ortho- hydroxy, carboxy, thiol, mercapto, amino, or hydrazido substitution (N-N Bidentates, N-N Tetradentates, and N-N Hexadentates)	$RR'C=N-N=CR''R'''$ or $RR'C=N-NR''R'''$ (for ketazines), where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho- hydroxy, carboxy, thiol, mercapto, amino, or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #17:</u> Schiff Bases with one Imine (C=N) Group and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution (N Monodentates)	$RR'C=N-R''$, where R, R', and R'' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Not including ortho-, alpha-, or beta-hydroxy, carboxy, carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N Valence Stabilizer #18:</u> Isocyanide and Cyanamide and related ligands (N Monodentates)	Isocyanides, cyanamides, and related ligands where the nitrogen atom is directly complexed to the high valence metal ion.
<u>N Valence Stabilizer #19:</u> Nitrosyl and Nitrite and related ligands (N Monodentates)	Nitrosyl, nitrite, and related ligands where the nitrogen atom is bound directly to the high valence metal ion.
<u>N Valence Stabilizer #20:</u> Nitriles, Dinitriles, and Polynitriles (N Monodentates, N-N Bidentates, and N-N-N Tridentates)	$R-CN$, $R-(CN)_2$, $R-(CN)_x$, etc. where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N Valence Stabilizer #21:</u> Azide ligands (N Monodentates, or N-N	Azide ($-N_3$) ligands bound directly to the high valence metal ion. Also includes organoazide

Bidentates)	derivatives (R-N ₃), triazenido compounds (R-N ₃ -R'), phosphonyl azides (R-PO ₂ H-N ₃), phosphoryl azides (O-PO ₂ H-N ₃), and sulfonyl azides (R-SO ₂ -N ₃) where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached
<u>S Valence Stabilizer #1:</u> Monothioethers (S Monodentates) wherein at least one Sulfur Atom is a Binding Site	SH ₂ , SHR, SR ₂ , where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>S Valence Stabilizer #2:</u> Disulfides (S Monodentates) wherein at least one Sulfur Atom is a Binding Site	R-S-S-R', where R and R' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>S Valence Stabilizer #3:</u> Dithioethers (S-S Bidentates) wherein at least one Sulfur Atom is a Binding Site	R-S-R'-S-R'', where R, R', and R'' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>S Valence Stabilizer #4:</u> Trithioethers (S-S Bidentates or S-S Tridentates) wherein at least one Sulfur Atom is a Binding Site	R-S-R'-S-R''-S-R''', where R, R', R'', and R''' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>S Valence Stabilizer #5:</u> Tetrathioethers (S-S Bidentates, S-S Tridentates, or S-S Bidentates) wherein at least one Sulfur Atom is a Binding Site	R-S-R'-S-R''-S-R'''-S-R''''', where R, R', R'', R''', and R'''' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.

<p><u>S Valence Stabilizer #6:</u> Hexathioethers (S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexadentates) wherein at least one Sulfur Atom is a Binding Site</p>	<p>$R-S-R'-S-R''-S-R'''-S-R''''-S-R'''''-S-R''''''$, where R, R', R'', R''', R'''', R''''', and R'''''' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.</p>
<p><u>S Valence Stabilizer #7:</u> Five-Membered Heterocyclic Rings containing One or Two Sulfur Atoms wherein at least one Sulfur Atom is a Binding Site (S Monodentates or S-S Bidentates)</p>	<p>Five membered heterocyclic ring containing one or two sulfur atoms, both of which may function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, N, P, As, or Se atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S Valence Stabilizer #8:</u> Six-Membered Heterocyclic Rings containing One or Two Sulfur Atoms wherein at least one Sulfur Atom is a Binding Site (S Monodentates or S-S Bidentates)</p>	<p>Six membered heterocyclic ring containing just one or two sulfur atoms, both of which may function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, N, P, As, or Se atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S Valence Stabilizer #9:</u> Five-Membered Heterocyclic Rings containing One or Two Sulfur Atoms and having at least one additional Sulfur Atom Binding Site not in a Ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexadentates)</p>	<p>Five membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional sulfur-containing substituents (usually thiols or thioethers) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As or Se atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S Valence Stabilizer #10:</u> Six-Membered Heterocyclic Rings containing One or Two Sulfur Atoms and</p>	<p>Six membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional sulfur-containing</p>

having at least one additional Sulfur Atom Binding Site not in a Ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexadentates)	substituents (usually thiols or thioethers) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As or Se atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #11:</u> Five-Membered Heterocyclic Rings containing One or Two Sulfur Atoms and having at least one additional Sulfur Atom Binding Site in a separate Ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexadentates)	Five membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional sulfur-containing rings that constitute S binding sites. Can include other ring systems bound to the S-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As, or Se atoms. This 5-membered ring(s) and/or additional S-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #12:</u> Six-Membered Heterocyclic Rings containing One or Two Sulfur Atoms and having at least one additional Sulfur Atom Binding Site in a separate Ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexadentates)	Six membered heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional sulfur-containing rings that constitute S binding sites. Can include other ring systems bound to the S-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As, or Se atoms. This 6-membered ring(s) and/or additional S-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #13:</u> Two-, Three-, Four-, Five-, Six-, Seven-, Eight-, Nine-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur (usually thiol or thioether groups) and are not contained in Component	Macrocyclic ligands containing two to ten sulfur binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups

Heterocyclic Rings (S-S Bidentates, S-S Tridentates, S-S Tetracentates, and S-S Hexacentates)	attached.
<u>S Valence Stabilizer #14:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur and are contained in Component 5-Membered Heterocyclic Rings (S-S Tridentates, S-S Tetracentates or S-S Hexacentates)	Macrocyclic ligands containing a total of four to ten five-membered heterocyclic rings containing sulfur binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S Valence Stabilizer #15:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur and are contained in a Combination of 5-Membered Heterocyclic Rings and Thiol, Thioether, or Thioketo Groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates)	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide sulfur binding sites to valence stabilize the central metal ion. Other thiol, thioether, or thioketo binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four to ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S Valence Stabilizer #16:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur and are contained in Component 6-Membered Heterocyclic Rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates)	Macrocyclic ligands containing a total of four to ten six-membered heterocyclic rings containing sulfur binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S Valence Stabilizer #17:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur and are contained in a Combination of 6-Membered Heterocyclic Rings and Thiol,	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These heterocyclic rings provide sulfur binding sites to valence stabilize the central metal ion. Other thiol, thioether, or thioketo binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four to ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but

Thioether, or Thioketo Groups (S-S Tridentates, S-S Tetradentates, or S-S Hexadentates)	they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S Valence Stabilizer #18:</u> Dithiobiurets (Dithioimidodicarbonic Diamides), Dithioisobiurets, Dithiobiureas, Trithiotriurets, Trithiotriureas, Bis(dithiobiurets), Bis(dithioisobiurets), Bis(dithiobiureas), Poly(dithiobiurets), Poly(dithioisobiurets), and Poly(dithiobiureas) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$RR'-N-C(=S)-NR''-C(=S)-NR'''R''''$ for dithiobiurets, and $RR'-N-C(=S)-NR''-NH-C(=S)-NR'''R''''$ for dithiobiureas, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #19:</u> Thioacylthioureas, Thioaroylthioureas, Bis(thioacylthioureas), Bis(thioaroylthioureas), Poly(thioacylthioureas), and Poly(thioaroylthioureas) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$RR'-N-C(=S)-NR''-C(=S)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #20:</u> Dithioacyl disulfides, Bis(dithioacyl disulfides), and Poly(dithioacyl disulfides) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$R-C(=S)-S-S-C(=S)-R'$ where R, and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #21:</u> Tetrathioperoxydicarbonic Diamides, Bis(tetrathioperoxydicarbonic diamides), and poly(tetrathioperoxydicarbonic diamides) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$RR'-N-C(=S)-S-S-C(=S)-N-R''R'''$ where R, R', R'', R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #22:</u> Hexathio-, Pentathio-, and Tetrathioperoxydicarbonic Acids, Bis(hexathio-, pentathio-, and tetrathioperoxydicarbonic acids), poly(hexathio-, pentathio-, and tetrathioperoxydicarbonic acids), and derivatives thereof (S-S Bidentates, S-S	$R-S-C(=S)-S-S-C(=S)-S-R'$ for hexathioperoxydicarbonic acids, $R-O-C(=S)-S-S-C(=S)-S-R'$ for pentathioperoxydicarbonic acids, and $R-O-C(=S)-S-S-C(=S)-O-R'$ for tetrathioperoxydicarbonic acids, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen

Tridentates, S-S Tetracentates)	or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #23:</u> Dithioperoxydiphosphoramides, Bis(dithioperoxyphosphoramides), and Poly(dithioperoxydiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$(RR'-N-)(R''R''''-N-)P(=S)-S-S-P(=S)(-N-R''''R''''''-)(-N-R''''''R''''''''-)$, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #24:</u> Dithioperoxydiphosphoric Acids, Bis(dithioperoxyphosphoric Acids), Poly(dithioperoxydiphosphoric Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$(R-O-)(R'-O-)P(=S)-S-S-P(=S)(-O-R'')(-O-R''')$; $(R-O-)(R'-S-)P(=S)-S-S-P(=S)(-S-R'')(-O-R''')$; or $(R-S-)(R'-S-)P(=S)-S-S-P(=S)(-S-R'')(-S-R''')$, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #25:</u> Dithioimidodiphosphonic Acids, Dithiohydrazidodiphosphonic Acids, Bis(dithioimidodiphosphonic acids), Bis(dithiohydrazidodiphosphonic acids), Poly(dithioimidodiphosphonic acids), Poly(dithiohydrazidodiphosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, and S-S Tetracentates)	$(R-O-)(R'-)P(=S)-NH-P(=S)(-R'')(-O-R''')$; $(R-S-)(R'-)P(=S)-NH-P(=S)(-R'')(-O-R''')$; or $(R-S-)(R'-)P(=S)-NH-P(=S)(-R'')(-S-R''')$ for dithioimidodiphosphonic acids, and $-NH-NH-$ derivatives for dithiohydrazidodiphosphonic acids, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #26:</u> Dithioimidodiphosphonamides, Dithiohydrazidodiphosphonamides, Bis(dithioimidodiphosphonamides), Bis(dithiohydrazidodiphosphonamides), Poly(dithioimidodiphosphonamides), and Poly(dithiohydrazidodiphosphonamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	$(RR'-N-)(R''-)P(=S)-NH-P(=S)(-R''')(-N-R''''R''''''-)$ for dithioimidodiphosphonamides, and $(RR'-N-)(R''-)P(=S)-NH-NH-P(=S)(-R''')(-N-R''''R''''''-)$ for dithiohydrazidodiphosphonamides, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.

	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #27:</u> Dithiodiphosphonamides, Bis(dithiodiphosphonamides), and Poly(dithiodiphosphonamides) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	(RR'-N-)(R'')P(=S)-S-P(=S)(-R''')(-N-R''''R'''''), or (RR'-N-)(R'')P(=S)-O-P(=S)(-R''')(-N-R''''R'''''), where R, R', R'', R''', R''''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #28:</u> Dithiodiphosphonic Acids, Bis(dithiodiphosphonic Acids), Poly(dithiodiphosphonic Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	(R-O-)(R')P(=S)-O-P(=S)(-R'')(-O-R'''); (R-O-)(R')P(=S)-S-P(=S)(-R'')(-O-R'''); (R-S-)(R')P(=S)-O-P(=S)(-R'')(-S-R'''); or (R-S-)(R')P(=S)-S-P(=S)(-R'')(-S-R'''); where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #29:</u> Dithioperoxydiphosphonamide, Bis(dithioperoxyphosphonamide), and Poly(dithioperoxydiphosphonamide) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	(RR'-N-)(R'')P(=S)-S-S-P(=S)(-R''')(-N-R''''R'''''), where R, R', R'', R''', R''''', and R'''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #30:</u> Dithioperoxydiphosphonic Acids, Bis(dithioperoxyphosphonic Acids), Poly(dithioperoxydiphosphonic Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	(R-O-)(R')P(=S)-S-S-P(=S)(-R'')(-O-R'''); or (R-S-)(R')P(=S)-S-S-P(=S)(-R'')(-S-R'''), where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #31:</u> Dithiophosphonic Acids (Phosphonodithioic Acids), Bis(dithiophosphonic Acids), Poly(dithiophosphonic Acids), and	(O=)PR(-S-R')(-S-R'') or (S=)PR(-S-R')(-O-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or

derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #32:</u> Trithiophosphonic Acids (Phosphonotrithioic Acids), Bis(trithiophosphonic Acids), Poly(trithiophosphonic Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(S=)PR(-S-R')(-S-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #33:</u> Phosphono(dithioperoxo)thioic Acids, Bis[phosphono(dithioperoxo)thioic Acids], Poly[phosphono(dithioperoxo)thioic Acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(O=)PR(-S-S-R')(-S-R'') or (S=)PR(-S-S-R')(-O-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #34:</u> Phosphono(dithioperoxo)dithioic Acids, Bis[phosphono(dithioperoxo)dithioic Acids], Poly[phosphono(dithioperoxo)dithioic Acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates)	(S=)PR(-S-S-R')(-S-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #35:</u> S-(Alkylthio)thiocarboxylic Acids, S-(Arylthio)thiocarboxylic Acids, and S,S-thiobisthiocarboxylic Acids (S-S Bidentates and S-S Tridentates)	R-S-R'CSOH or R-S-R'CSSH for S-(alkylthio)thiocarboxylic and S-(arylthio)thiocarboxylic acids, and HSOCR-S-R'COSH or HSSCR-S-R'CSSH for S,S-thiobisthiocarboxylic acids, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #36:</u> S-(Alkyldisulfido)thiocarboxylic Acids, S-(Aryldisulfido)thiocarboxylic Acids, and S,S'-Disulfidobisthiocarboxylic Acids (S-S Bidentates and S-S Tridentates)	R-S-S-R'CSOH or R-S-S-R'CSSH for S-(alkyldisulfido)thiocarboxylic and S-(aryldisulfido)thiocarboxylic acids, and HSOCR-S-S-R'COSH or HSSCR-S-S-R'CSSH for S,S'-disulfidobisthiocarboxylic acids, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen

	or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #37:</u> 1,2-Dithiolates, Bis(1,2-dithiolates), and Poly(1,2-dithiolates) (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$R-CH(-SR'')-CH(-SR''')-R'$, and $R-C(-SR'')=C(-SR''')-R'$, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #38:</u> Rhodanines and Bis(rhodanines) (S-S Bidentates and S-S Tetradentates)	$RN-C(=O)-CHR'-S-C(=S)$ for rhodanines, and $R-[N-C(=O)-CHR'-S-C(=S)]_2$ for bis(rhodanines), where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #39:</u> Dithiocarbimates, Bis(dithiocarbimates), and Poly(dithiocarbimates) (S-S Bidentates, S-S Tridentates, and S-S Tetradentates)	$RN=C(SH)(SH)$, where R represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #40:</u> Thioxanthates, Bis(thioxanthates), and Poly(thioxanthates) (S-S Bidentates and S-S Tetradentates)	$RS^+=C(SH)(SH)$ or $RS-C(=S)(SH)$, where R represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #41:</u> Xanthates, Bis(xanthates), and Poly(xanthates) (S-S Bidentates and S-S Tetradentates)	$RO^+=C(SH)(SH)$ or $RO-C(=S)(SH)$, where R represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #42:</u>	Typically $RR'R''P=C(SH)(SH)$ [pentavalent P],

Phosphinodithioformates (S-S Bidentates)	although $RR'P-C(=S)(SH)$ [trivalent P] may be acceptable in some situations, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #43:</u> Alkyl- and Aryl- Dithioborates, Trithioborates, Perthioborates, Bis(dithioborates), Bis(trithioborates), and Bis(perthioborates) (S-S Bidentates and S-S Tetradentates)	$R-S-C(-S-R'')-O-R'$ for dithioborates, $R-S-C(-S-R'')-S-R'$ for trithioborates, and $R-S-S-C(-S-R'')-S-R'$ for perthioborates, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #44:</u> Alkyl- and Aryl- Dithioboronates, and Bis(dithioboronates) (S-S Bidentates and S-S Tetradentates)	$R-C(-S-R'')-S-R'$, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #45:</u> Trithioarsonic Acids (Arsonotrithioic Acids), Dithioarsonic Acids (Arsonodithioic Acids), Tetrathioarsonic Acids (Arsonotetrathioic Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$(O=)As(-S-R)(-S-R')(-S-R'')$ or $(S=)As(-S-R)(-S-R')(-O-R'')$ for trithioarsonic acid; $(O=)As(-O-R)(-S-R')(-S-R'')$ or $(S=)As(-S-R)(-O-R')(-O-R'')$ for dithioarsonic acid, or $(S=)As(-S-R)(-S-R')(-S-R'')$ for tetrathioarsonic acid, where R, R', and R'' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #46:</u> Trithioantimonic Acids (Stibonotrithioic Acids), Dithioantimonic Acids (Stibonodithioic Acids), Tetrathioantimonic Acids (Stibonotetrathioic Acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetradentates)	$(O=)Sb(-S-R)(-S-R')(-S-R'')$ or $(S=)Sb(-S-R)(-S-R')(-O-R'')$ for trithioantimonic acid; $(O=)Sb(-O-R)(-S-R')(-S-R'')$ or $(S=)Sb(-S-R)(-O-R')(-O-R'')$ for dithioantimonic acid, or $(S=)Sb(-S-R)(-S-R')(-S-R'')$ for tetrathioantimonic acid, where R, R', and R'' represent H, NH_2 or any organic functional

	group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #47:</u> Phosphine P-sulfides and Amino-substituted Phosphine sulfides (S Monodentates)	$RR'R''P=S$ for phosphine P-sulfides, and $(RR'N)(R''R'''N)(R''''R'''''N)P=S$ for amino-substituted phosphine sulfides, where R, R', R'', R''', R''', and R''''' represent H, Cl, Br, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Rs are typically aromatic or heterocyclic for phosphine P-sulfides.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #48:</u> Arsine As-sulfides and Amino-substituted Arsine sulfides (S Monodentates)	$RR'R''As=S$ for arsine As-sulfides, and $(RR'N)(R''R'''N)(R''''R'''''N)As=S$ for amino-substituted arsine sulfides, where R, R', R'', R''', R''', and R''''' represent H, Cl, Br, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Rs are typically aromatic or heterocyclic for arsine As-sulfides.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S Valence Stabilizer #49:</u> Thiolates (S Monodentates)	Thiols ($HS-R$, $HS-R-SH$, etc.), where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S Valence Stabilizer #50:</u> Sulfide ligands (S Monodentates)	Sulfide ($-S^{2-}$) ligands bound directly to the high valence metal ion.
<u>P Valence Stabilizer #1:</u> Monophosphines (P Monodentates) wherein at least one Phosphorus Atom is a Binding Site	PH_3 , PH_2R , PHR_2 , and PR_3 where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #2:</u> Diphosphines (a P-P Bidentate) wherein at	$R'-P-R-P-R''$, where R, R', and R'' represent H or any organic functional group wherein the

least one Phosphorus Atom is a Binding Site	number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #3:</u> Triphosphines (either P-P Bidentates or P-P-P Tridentates) wherein at least one Phosphorus Atom is a Binding Site	$R-P-R'-P-R''-P-R'''$, where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #4:</u> Tetraphosphines (P-P Bidentates, P-P-P Tridentates, or P-P-P-P Tetracentates) wherein at least one Phosphorus Atom is a Binding Site	$R-P-R'-P-R''-P-R'''-P-R''''$, where R, R', R'', R''', and R'''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #5:</u> Pentaphosphines (P-P Bidentates, P-P-P Tridentates, or P-P-P-P Tetracentates) wherein at least one Phosphorus Atom is a Binding Site	$R-P-R'-P-R''-P-R'''-P-R''''-P-R'''''$, where R, R', R'', R''', R'''', and R''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #6:</u> Hexaphosphines (P-P Bidentates, P-P-P Tridentates, P-P-P-P Tetracentates, or P-P-P-P-P Hexacentates) wherein at least one Phosphorus Atom is a Binding Site	$R-P-R'-P-R''-P-R'''-P-R''''-P-R'''''-P-R''''''$, where R, R', R'', R''', R'''', R''''', and R'''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>P Valence Stabilizer #7:</u> Five-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms wherein at least one Phosphorus Atom is a Binding Site (P Monodentates or P-P Bidentates)	Five membered heterocyclic ring containing one, two, or three phosphorus atoms, all of which may or may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, N, As, or Se atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-

	insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #8:</u> Six-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms wherein at least one Phosphorus Atom is a Binding Site (P Monodentates or P-P Bidentates)	Six membered heterocyclic ring containing one, two, or three phosphorus atoms, all of which may or may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, N, As, or Se atoms. This 6-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #9:</u> Five-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms at least one additional Phosphorus Atom Binding Site not in a Ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexadentates)	Five membered heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional phosphorus-containing substituents (usually phosphines) that constitute P binding sites. Can include other ring systems bound to the heterocyclic ring or to the P-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, As or Se atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or P-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #10:</u> Six-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms at least one additional Phosphorus Atom Binding Site not in a Ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexadentates)	Six membered heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional phosphorus-containing substituents (usually phosphines) that constitute P binding sites. Can include other ring systems bound to the heterocyclic ring or to the P-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, As or Se atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or P-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #11:</u> Five-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms at least one additional Phosphorus Atom Binding Site in a separate Ring (P Monodentates, P-P Bidentates, P-P	Five membered heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional phosphorus-containing rings that constitute P binding sites. Can include other ring systems bound to the P-containing heterocyclic rings, but they do not

Tridentates, P-P Tetracentates, or P-P Hexadentates)	coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, As, or Se atoms. This 5-membered ring(s) and/or additional P-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #12:</u> Six-Membered Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms at least one additional Phosphorus Atom Binding Site in a separate Ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexadentates)	Six membered heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional phosphorus-containing rings that constitute P binding sites. Can include other ring systems bound to the P-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, As, or Se atoms. This 6-membered ring(s) and/or additional P-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #13:</u> Two-, Three-, Four-, Five-, Six-, and Eight-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Phosphorus and are not contained in Component Heterocyclic Rings (P-P Bidentates, P-P Tridentates, P-P Tetracentates, and P-P Hexadentates)	Macrocyclic ligands containing two, three, four, five, six, or eight phosphorus binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P Valence Stabilizer #14:</u> Four-, Six-, or Eight-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Phosphorus and are contained in Component 5-Membered Heterocyclic Rings (P-P Tridentates, P-P Tetracentates, or P-P Hexadentates)	Macrocyclic ligands containing a total of four, six, or eight five-membered heterocyclic rings containing phosphorus binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>P Valence Stabilizer #15:</u> Four-, Six-, or Eight-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide phosphorus binding sites to valence stabilize the central metal ion. Other phosphine binding sites can also be included in the macrocyclic ligand, so long as

Phosphorus and are contained in a Combination of 5-Membered Heterocyclic Rings and Phosphine Groups (P-P Tridentates, P-P Tetradentates, or P-P Hexadentates)	the total number of binding sites is four, six, or eight. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>P Valence Stabilizer #16:</u> Four-, Six-, or Eight-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Phosphorus and are contained in Component 6-Membered Heterocyclic Rings (P-P Tridentates, P-P Tetradentates, or P-P Hexadentates)	Macrocyclic ligands containing a total of four, six, or eight six-membered heterocyclic rings containing phosphorus binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>P Valence Stabilizer #17:</u> Four-, Six-, or Eight-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Phosphorus and are contained in a Combination of 6-Membered Heterocyclic Rings and Phosphine Groups (P-P Tridentates, P-P Tetradentates, or P-P Hexadentates)	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These heterocyclic rings provide phosphorus binding sites to valence stabilize the central metal ion. Other phosphine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, six, or eight. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>O Valence Stabilizer #1:</u> Dithioperoxydicarbonic Acids, Bis(dithioperoxydicarbonic acids), poly(dithioperoxydicarbonic acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetradentates)	$R-O-C(=O)-S-S-C(=O)-O-R'$, where R and R' represent H, NH_2 or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #2:</u> Imidodiphosphonic Acids, Hydrazidodiphosphonic Acids, Bis(imidodiphosphonic Acids), Bis(hydrazidodiphosphonic Acids), Poly(imidodiphosphonic Acids),	$(R-O-)(R'-)P(=O)-NH-P(=O)-(R'')(-O-R''')$ for imidodiphosphonic acids, and $(R-O-)(R'-)P(=O)-NH-NH-P(=O)-(R'')(-O-R''')$ for hydrazidodiphosphonic acids; where R, R', R'', and R''' represent H, NH_2 or any organic functional group wherein the number of carbon

Poly(hydrazidodiphosphonic Acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #3:</u> Imidodiphosphonamides, Hydrazidodiphosphonamides, Bis(imidodiphosphonamides), Bis(hydrazidodiphosphonamides), Poly(imidodiphosphonamides), and Poly(hydrazidodiphosphonamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(RR'-N-)(R''-)P(=O)-NH-P(=O)(-R''')(-N-R''''R''''')$ for imidodiphosphonamides, and –NH-NH- derivatives for hydrazidodiphosphonamides, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #4:</u> Diphosphonamides, Bis(diphosphonamides), and Poly(diphosphonamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(RR'-N-)(R''-)P(=O)-O-P(=O)(-R''')(-N-R''''R''''')$, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #5:</u> Carbazates (carbazides), Bis(carbazates), and Poly(carbazates) (O-O Bidentates, O-O Tridentates, and O-O Tetracentates; or possibly N-O Bidentates, N-O Tridentates, and N-O Tetracentates)	$RR'N-NR''-C(=O)(OH)$, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #6:</u> Arsonic Acids, Bis(arsonic acids), Poly(arsonic acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates)	$(O=)As(-O-R)(-O-R')(-O-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #7:</u> Alkyl- and Aryl- Borates and Bis(borates) (O-O Bidentates and O-O Tetracentates)	$R-O-C(-O-R'')(-O-R')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-

	insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #8:</u> Alkyl- and Aryl- Boronates and Bis(boronates) (O-O Bidentates and O-O Tetradentates)	$R-C(-O-R'')-O-R'$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #9:</u> Phosphine P-oxides and Amino-substituted Phosphine oxides (O Monodentates)	$RR'R''P=O$ for phosphine P-oxides, and $(RR'N)(R''R''''N)(R''''R''''''N)P=O$ for amino-substituted phosphine oxides, where R, R', R'', R''', R'''', and R''''' represent H, Cl, Br, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Rs are typically aromatic or heterocyclic for phosphine P-oxides.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #10:</u> Arsine As-oxides and Amino-substituted Arsine oxides (O Monodentates)	$RR'R''As=O$ for arsine As-oxides, and $(RR'N)(R''R''''N)(R''''R''''''N)As=O$ for amino-substituted arsine oxides, where R, R', R'', R''', R'''', and R''''' represent H, Cl, Br, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. (Rs are typically aromatic or heterocyclic for arsine As-oxides.) Ligand can also contain nonbinding N, O, S, or P atoms.
<u>O Valence Stabilizer #11:</u> Five-Membered Heterocyclic Rings containing One or Two Oxygen Atoms wherein at least one Oxygen Atom is a Binding Site (O Monodentates or O-O Bidentates)	Five membered heterocyclic ring containing one or two oxygen atoms, both of which may or may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, or P atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #12:</u> Six-Membered Heterocyclic Rings	Six membered heterocyclic ring containing one or two oxygen atoms, both of which may or

containing One or Two Oxygen Atoms wherein at least one Oxygen Atom is a Binding Site (O Monodentates or O-O Bidentates)	may not function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, or P atoms. This 6-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #13:</u> Five-Membered Heterocyclic Rings containing One or Two Oxygen Atoms and having at least one additional Oxygen Atom Binding Site not in a Ring (O Monodentates, O-O Bidentates, O Tridentates, O Tetracentates, or O Hexadentates)	Five membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxyl or ester groups) that constitute O binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #14:</u> Six-Membered Heterocyclic Rings containing One or Two Oxygen Atoms and having at least one additional Oxygen Atom Binding Site not in a Ring (O Monodentates, O-O Bidentates, O Tridentates, O Tetracentates, or O Hexadentates)	Six membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxyl or ester groups) that constitute O binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #15:</u> Five-Membered Heterocyclic Rings containing One or Two Oxygen Atoms and having at least one additional Oxygen Atom Binding Site in a Separate Ring (O Monodentates, O-O Bidentates, O Tridentates, O Tetracentates, or O Hexadentates)	Five membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional oxygen-containing rings that constitute O binding sites. Can include other ring systems bound to the O-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 5-membered ring(s) and/or additional O-containing ring(s) and/or attached,

	uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #16:</u> Six-Membered Heterocyclic Rings containing One or Two Oxygen Atoms and having at least one additional Oxygen Atom Binding Site in a Separate Ring (O Monodentates, O-O Bidentates, O Tridentates, O Tetradentates, or O Hexadentates)	Six membered heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional oxygen-containing rings that constitute O binding sites. Can include other ring systems bound to the O-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This 6-membered ring(s) and/or additional O-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #17:</u> Four-, Five-, Six-, Seven-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen (usually ester or hydroxyl groups) and are not contained in Component Heterocyclic Rings (O-O Bidentates, O-O Tridentates, O-O Tetradentates, and O-O Hexadentates)	Macrocyclic ligands containing four, five, six, seven, eight, or ten oxygen binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #18:</u> Four-, Five-, Six-, Seven-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen and are contained in Component 5-Membered Heterocyclic Rings (O-O Bidentates, O-O Tridentates, O-O Tetradentates, and O-O Hexadentates)	Macrocyclic ligands containing a total of four, five, six, seven, eight, or ten five-membered heterocyclic rings containing oxygen binding sites. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>O Valence Stabilizer #19:</u> Four-, Five-, Six-, Seven-, Eight-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen and are contained in Component 6-Membered Heterocyclic Rings (O-O Bidentates, O-O Tridentates,	Macrocyclic ligands containing a total of four, five, six, seven, eight, or ten six-membered heterocyclic rings containing oxygen binding sites. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-

O-O Tetradentates, and O-O Hexadentates)	insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #1:</u> Thioimides, Dithioimides, Polythioimides, and Derivatives of Thioimidic Acid (N-S Bidentates and N-S Tetradentates)	$RC(=NH)SR'$, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #2:</u> Thioguanylureas, Guanidinothioureas, Bis(thioguanylureas), Bis(guanidinothioureas), Poly(thioguanylureas), and Poly(guanidinothioureas) (N-S Bidentates and N-S Tetradentates)	$RR'-N-C(=NH)-NR''-CS-NR'''R''''$ for thioguanylureas, and $RR'-N-C(=NH)-NR''-NH-CS-NR'''R''''$ for guanidinothioureas, where R, R', R'', R''', and R'''' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #3:</u> Amidinothioamides, Guanidinothioamides, Bis(amidinothioamides), Bis(guanidinothioamides), Poly(amidinothioamides), and Poly(guanidinothioamides) (including both N-amidinothioamides and 2- amidinothioacetamides) (N-S Bidentates and N-S Tetradentates)	$RR'-N-C(=NH)-NR''-CS-R'''$ for N-amidinothioamides, or $RR'-N-C(=NH)-CR''R'''-CS-N-R''''R'''''$ for 2-amidinothioacetamides, and $RR'-N-C(=NH)-NR''-NH-CS-R'''$ for guanidinothioamides, where R, R', R'', R''', R''', and R''''' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #4:</u> Imidoylthioamides, Bis(imidoylthioamides), and Poly(imidoylthioamides) (N-S Bidentates and N-S Tetradentates)	$R-C(=NH)-NR'-CS-R''$, where R, R', and R'', represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #5:</u> Thioureas, Bis(thioureas), and Poly(thioureas), including Thiourylene Complexes (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	$RR'NCSNR''R'''$, where R, R', R'', and R''' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #6:</u>	$RCSNR'R''$, where R, R', and R'' represent H,

Thiocarboxamides, Bis(thiocarboxamides), and Poly(thiocarboxamides) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #7:</u> Imidosulfurous Diamides and Bis(imidosulfurous diamides) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	RR'-N-S(=NH)-N-R''R''', where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #8:</u> Sulfurdiimines, Bis(sulfurdiimines), and Poly(sulfurdiimines) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	R-N=S=N-R', where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #9:</u> Phosphonimidothioic Acid, Phosphonimidodithioic Acid, Bis(Phosphonimidothioic acid); Bis(Phosphonimidodithioic acid), and derivatives thereof (N-S Bidentates, N-S Tetradentates)	(NH=)PR(OR')(SR'') for phosphonimidothioic acid and (NH=)PR(SR')(SR'') for phosphonimidodithioic acid, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #10:</u> Phosphonothioic Diamides, Bis(phosphonothioic diamides), and Poly(phosphonothioic diamides) (N-S Bidentates and N-S Tetradentates)	(S=)PR(-NR'R'')(-NR'''R'''), where R, R', R'', R''', and R'''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #11:</u> Phosphonamidothioic Acid, Phosphonamidimidodithioic Acid, Bis(phosphonamidothioic acid), Bis(phosphonamidimidodithioic acid), poly(phosphonamidothioic acid), and poly(phosphonamidimidodithioic acid), and derivatives thereof (N-S Bidentates and N-S Tetradentates)	(S=)PR(-NR'R'')(-OR''') or (O=)PR(-NR'R'')(-SR''') for phosphonamidothioic acid, (S=)PR(-NR'R'')(-SR''') for phosphonamidimidodithioic acid, where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N,

	O, S, or P atoms.
<u>N-S Valence Stabilizer #12:</u> Beta-Aminothiones (N-Substituted 3-amino-2-propenethioaldehydes), Bis(beta-aminothiones), and Poly(beta-aminothiones) (N-S Bidentates and N-S Tetradentates)	$R-C(=S)-CR'=CR''-NHR'''$, where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #13:</u> 3-Aminothioacrylamides (3-Amino-2-thiopropenamides), 3,3-Diaminothioacrylamides, Bis(3-aminothioacrylamides), Bis(3,3-diaminoacrylamides), Poly(3-aminothioacrylamides), and Poly(3,3-diaminothioacrylamides) (N-S Bidentates and N-S Tetradentates)	$RR'-N-C(=S)-CR''=C(-NHR''')R''''$ for 3-aminothioacrylamides, and $RR'-N-C(=S)-CR''=C(-NHR''')(-NR''''R''''')$ for 3,3-diaminothioacrylamides, where R, R', R'', R''', R'''', R''''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #14:</u> 3-Aminothioacrylic Acids (3-Amino-2-thiopropenoic acids), 3-Mercapto-3-aminothioacrylic acids, Bis(3-aminothioacrylic acids), Bis(3-Hydroxy-3-aminothioacrylic acids), Poly(3-aminothioacrylic acids), and Poly(3-Hydroxy-3-aminothioacrylic acids), and derivatives thereof (N-S Bidentates and N-S Tetradentates)	$R-O-C(=S)-CR'=C(-NHR'')R'''$ or $R-S-C(=S)-CR'=C(-NHR'')R'''$ for 3-aminothioacrylic acids, and $R-O-C(=S)-CR'=C(-NHR'')(-S-R''')$ or $R-S-C(=S)-CR'=C(-NHR'')(-S-R''')$ for 3-mercapto-3-aminothioacrylic acids, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #15:</u> N-Thioacyl Benzylidenimines, Bis(N-thioacyl benzylidenimines), and Poly(N-thioacyl benzylidenimines) (N-S Bidentates and N-S Tetradentates)	$R-C(=S)-N=CHR'$, where R' represents an aromatic derivative (i.e., -C ₆ H ₅), and R represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #16:</u> Thiocarbonyl oximes, Bis(thiocarbonyl oximes), and Poly(thiocarbonyl oximes) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates)	$R-C(=S)-C(=NOH)-R'$, where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-

	insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #17:</u> Mercapto oximes, Bis(mercapto oximes), and Poly(mercapto oximes) (including 2-sulfur heterocyclic oximes) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	$R-CH(-SH)-C(=NOH)-R'$, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #18:</u> 2-Nitrothiophenols (2-nitrobenzenethiols) (N-S Bidentates)	$o-(O_2N-)(HS-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #19:</u> 2-Nitrilothiophenols (N-S Bidentates)	$o-(NC-(CH_2)_{0-1})(HS-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #20:</u> Thiohydrazides, Bis(thiohydrazides), and Poly(thiohydrazides) (N-S Bidentates and N-S Tetradentates)	$R-C(=S)-NHN R'R''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #21:</u> Thiosemicarbazides, Bis(thiosemicarbazides), and Poly(thiosemicarbazides) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates)	$RR'-N-C(=S)-NHN R''R'''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-S Valence Stabilizer #22:</u> Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) or	Macrocyclic ligands containing five, seven, or nine binding sites composed of nitrogen and sulfur to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached,

Sulfur (usually thiols, mercaptans, or thiocarbonyls) and are not contained in Component Heterocyclic Rings (N-S Tridentates, N-S Tetradentates, and N-S Hexadentates)	uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-S Valence Stabilizer #23:</u> Five-, or Seven-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Sulfur and are contained in Component Heterocyclic Rings (N-S Tridentates, N-S Tetradentates, or N-S Hexadentates)	Macrocyclic ligands containing a total of five or seven heterocyclic rings containing nitrogen or sulfur binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N-S Valence Stabilizer #24:</u> Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Sulfur and are contained in a Combination of Heterocyclic Rings and Amine, Imine, Thiol, Mercapto, or Thiocarbonyl Groups (N-S Tridentates, N-S Tetradentates, or N-S Hexadentates)	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide nitrogen or sulfur binding sites to valence stabilize the central metal ion. Other amine, imine, thiol, mercapto, or thiocarbonyl binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is five, seven, or nine. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N-O Valence Stabilizer #1:</u> Imidates, Diimidates, Polyimidates, and Derivatives of Imidic Acid (N-O Bidentates and N-O Tetradentates)	$RC(=NH)OR'$, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #2:</u> Pseudoureas, bis(pseudoureas), and poly(pseudoureas) (N-O Bidentates and N-O Tetradentates)	$RR'NC(=NH)OR''$, where R, R', and R'' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #3:</u>	$RR'NC(=NH)CR''R'''(CO)OR''''$, where R, R',

2-Amidinoacetates, Bis(2-amidinoacetates), and Poly(2-amidinoacetates) (N-O Bidentates and N-O Tetracentates)	R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #4:</u> Ureas, Bis(ureas), and Poly(ureas), including Urylene Complexes (N-O Bidentates, N-O Tridentates, and N-O Tetracentates)	RR'NCONR''R''', where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #5:</u> Phosphonimidic Acid, Bis(phosphonimidic acid), Poly(phosphonimidic acid), and derivatives thereof (N-O Bidentates and N-O Tetracentates)	(NH=)PR(OR')(OR''), where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #6:</u> Phosphonamidic Acid, Phosphonic Diamide, Bis(Phosphonamidic Acid), Bis(Phosphonic Diamide), Poly(phosphonamidic acid), poly(phosphonic diamide), and derivatives thereof (N-O Bidentates and N-O Tetracentates)	(O=)PR(-NR'R'')(-OR''') for phosphonamidic acid and (O=)PR(-NR'R'')(-NR''''R''') for phosphonic diamide, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #7:</u> Beta-Ketoamines (N-Substituted 3-amino-2-propenals), Bis(beta-ketoamines), and Poly(beta-ketoamines) (N-O Bidentates and N-O Tetracentates)	R-C(=O)-CR'=C(-NHR'')R''', where R, R', R'', and R''' represent H, or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #8:</u> 3-Aminoacrylamides (3-Amino-2-propenamides), 3,3-Diaminoacrylamides, Bis(3-aminoacrylamides), Bis(3,3-diaminoacrylamides), Poly(3-	RR'-N-C(=O)-CR''=C(-NHR''')R'''' for 3-aminoacrylamides, and RR'-N-C(=O)-CR''=C(-NHR''')(-NR''''R''') for 3,3-diaminoacrylamides, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ , or any organic

aminoacrylamides), and Poly(3,3-diaminoacrylamides) (N-O Bidentates and N-O Tetracentates)	functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #9:</u> 3-Aminoacrylic Acids (3-Amino-2-propenoic acids), 3-Hydroxy-3-aminoacrylic acids, Bis(3-aminoacrylic acids), Bis(3-Hydroxy-3-aminoacrylic acids), Poly(3-aminoacrylic acids), and Poly(3-Hydroxy-3-aminoacrylic acids), and derivatives thereof (N-O Bidentates and N-O Tetracentates)	$R-O-C(=O)-CR'=C(-NHR'')R'''$ for 3-aminoacrylic acids, and $R-O-C(=O)-CR'=C(-NHR'')(-O-R''')$ for 3-hydroxy-3-aminoacrylic acids, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #10:</u> N-Acyl Benzylidenimines, Bis(N-acyl benzylidenimines), and Poly(N-acyl benzylidenimines) (N-O Bidentates and N-O Tetracentates)	$R-C(=O)-N=CHR'$, where R' represents an aromatic derivative (i.e., -C ₆ H ₅), and R represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #11:</u> 2-Nitroanilines (N-O Bidentates)	$o-(O_2N-)(RR'N-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, and R and R' represent H, NH ₂ , or alkyl or aryl hydrocarbon groups wherein the number of carbon atoms range from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #12:</u> 2-Nitrilophenols (N-O Bidentates). Also includes acylcyanamides.	$o-(NC-(CH_2)_{0-1})(HO-)Ar$, where Ar represents an aromatic group or heterocyclic wherein the number of carbon atoms ranges from 6 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>N-O Valence Stabilizer #13:</u> Amine N-Oxides and Diazine N-Oxides (Azoxy compounds) (N-O Bidentates, N-O Tridentates, and N-O Tetracentates)	$HetN^+-O^-$ for amine N-oxides, and $R-N=N^+(-O^-)-R'$ for diazine N-oxides (azoxy compounds), where Het represents a nitrogen-containing heterocyclic derivative wherein the number of

	carbon atoms ranges from 4 to 40, and R and R' represent separate or the same aromatic functionalities, both Het and R,R' optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N-O Valence Stabilizer #14: Hydrazides, Bis(hydrazides), and Poly(hydrazides) (N-O Bidentates and N-O Tetradentates)	$R-C(=O)-NHN R'R''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N-O Valence Stabilizer #15: Semicarbazides, Bis(semicarbazides), and Poly(semicarbazides) (N-O Bidentates, N-O Tetradentates, and N-O Hexadentates)	$RR'-N-C(=O)-NHN R''R'''$, where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
N-O Valence Stabilizer #16: Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) or Oxygen (usually hydroxy, carboxy, or carbonyl groups) and are not contained in Component Heterocyclic Rings (N-O Tridentates, N-O Tetradentates, and N-O Hexadentates)	Macrocyclic ligands containing five, seven, or nine binding sites composed of nitrogen and oxygen to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
N-O Valence Stabilizer #17: Five-, or Seven-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Oxygen and are contained in Component Heterocyclic Rings (N-O Tridentates, N-O Tetradentates, or N-O Hexadentates)	Macrocyclic ligands containing a total of five or seven heterocyclic rings containing nitrogen or oxygen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
N-O Valence Stabilizer #18: Five-, Seven-, or Nine-Membered Macrocyclics, Macrobicyclics, and	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide nitrogen or oxygen binding sites to

Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Oxygen and are contained in a Combination of Heterocyclic Rings and Amine, Imine, Hydroxy, Carboxy, or Carbonyl Groups (N-O Tridentates, N-O Tetracentates, or N-O Hexacentates)	valence stabilize the central metal ion. Other amine, imine, hydroxy, carboxy, or carbonyl binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is five, seven, or nine. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-O Valence Stabilizer #1:</u> Thiobiurets (Thioimidodicarbonic Diamides), Thioisobiurets, Thiobiureas, Thiotriurets, Thiotriureas, Bis(thiobiurets), Bis(thioisobiurets), Bis(thiobiureas), Poly(thiobiurets), Poly(thioisobiurets), Poly(thiobiureas) (S-O Bidentates, S-O Tridentates, S-O Tetracentates), and (3-formamidino thiocarbamides).	$RR'-N-C(=S)-NR''-C(=O)-NR'''R''''$ for thiobiurets, and $RR'-N-C(=S)-NR''-NH-C(=O)-NR'''R''''$ for thiobiureas, where R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #2:</u> Acylthiureas, Aroylthiureas, Thioacylureas, Thioaroylureas, Bis(acylthiureas), Bis(aroylthiureas), Bis(thioacylureas), Bis(thioaroylureas), Poly(thioacylthiureas), Poly(thioaroylthiureas), Poly(thioacylureas), and Poly(thioaroylureas) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RR'-N-C(=S)-NR''-C(=O)-R'''$ for acyl- and aroylthiureas, and $RR'-N-C(=O)-NR''-C(=S)-R'''$ for thioacyl- and thioaroylureas, where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #3:</u> Thioimidodialdehydes, Thiohydrazidodialdehydes (thioacyl hydrazides), Bis(thioimidodialdehydes), Bis(thiohydrazidodialdehydes), Poly(thioimidodialdehydes), and Poly(thiohydrazidodialdehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RC(=S)-NR'-C(=O)-R''$ for thioimidodialdehydes, and $RC(=S)-NR'-NH-C(=O)-R''$ for thiohydrazidodialdehydes (thioacyl hydrazides), where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #4:</u> Thioimidodicarbonic acids, Thiohydrazidodicarbonic acids,	$R-O-C(=S)-NR'-C(=O)-O-R''$ or $R-S-C(=S)-NR'-C(=O)-S-R''$ for thioimidodicarbonic acids, and $R-O-C(=S)-NR'-NH-C(=O)-O-R''$ or $R-S-$

Bis(thioimidodicarbonic acids), Bis(thiohydrazidodicarbonic acids), Poly(thioimidodicarbonic acids), Poly(thiohydrazidodicarbonic acids) and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetrاداتates)	$C(=S)-NR'-NH-C(=O)-S-R''$ for thiohydrazidodicarbonic acids, where R, R', and R'' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #5:</u> 1,2-Monothioketones (Monothioles), Monothio- α -ketonates), 1,2,3- Monothioketones, 1,2,3-Dithioketones, Monothiotropolonates, ortho- Monothioquinones, Bis(1,2- Monothioketones), and Poly(1,2- Monothioketones) (S-O Bidentates, S-O Tridentates, S-O Tetrاداتates)	$R-C(=S)-C(=O)-R'$ where R and R' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #6:</u> Trithioperoxydicarbonic Diamides, Dithioperoxydicarbonic Diamides, Bis(trithioperoxydicarbonic diamides), Bis(dithioperoxydicarbonic diamides), poly(trithioperoxydicarbonic diamides) and poly(dithioperoxydicarbonic diamides) (S- O Bidentates, S-O Tridentates, S-O Tetrاداتates)	$RR'-N-C(=S)-S-S-C(=O)-N-R''R'''$ for trithioperoxydicarbonic diamides, and $RR'-N-C(=O)-S-S-C(=O)-N-R''R'''$ for dithioperoxydicarbonic diamides, where R, R', R'', R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #7:</u> Diithiodicarbonic Acids, Bis(dithiodicarbonic acids), Poly(dithiodicarbonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetrاداتates)	$R-O-C(=S)-S-C(=O)-O-R'$, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #8:</u> Trithioperoxydicarbonic Acids, Bis(trithioperoxydicarbonic acids), poly(trithioperoxydicarbonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetrاداتates)	$R-O-C(=S)-S-S-C(=O)-O-R'$, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #9:</u>	$(RR'-N-)(R''R'''-N-)P(=S)-S-S-P(=O)(-N-$

Monothiooxydiphosphoramide, Bis(monothiooxyphosphoramide), and Poly(monothiooxydiphosphoramide) (S-O Bidentates, S-O Tridentates, S-O Tetridentates)	$R''''R'''''(-N-R''''''R''''''')$, where R, R', R'', R''', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #10:</u> Monothiooxydiphosphoric Acids, Bis(monothiooxyphosphoric Acids), Poly(monothiooxydiphosphoric Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates)	$(R-O)(R'-O)P(=S)-S-S-P(=O)(-O-R'')(-O-R''')$; $(R-O)(R'-S)P(=S)-S-S-P(=O)(-S-R'')(-O-R''')$; or $(R-S)(R'-S)P(=S)-S-S-P(=O)(-S-R'')(-S-R''')$, where R, R', R'', R''', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #11:</u> Monothioimidodiphosphonic Acids, Monothiohydrazidodiphosphonic Acids, Bis(monothioimidodiphosphonic Acids), Bis(monothiohydrazidodiphosphonic Acids), Poly(monothioimidodiphosphonic Acid), Poly(monothiohydrazidodiphosphonic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates)	$(R-O)(R'-)P(=S)-NH-P(=O)(-R'')(-O-R''')$; $(R-S)(R'-)P(=S)-NH-P(=O)(-R'')(-O-R''')$; or $(R-S)(R'-)P(=S)-NH-P(=O)(-R'')(-S-R''')$ for monothioimidodiphosphonic acids, and -NH-NH- derivatives for monothiohydrazidodiphosphonic acids, where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #12:</u> Monothioimidodiphosphonamides, Monothiohydrazidodiphosphonamides, Bis(monothioimidodiphosphonamides), Bis(monothiohydrazidodiphosphonamides) Poly(monothioimidodiphosphonamides), and Poly(monothiohydrazidodiphosphonamides) (S-O Bidentates, S-O Tridentates, S-O Tetridentates)	$(RR'-N)(R'')P(=S)-NH-P(=O)(-R''')(-N-R''''R''''')$ for monothioimidodiphosphonamides, and -NH-NH- derivatives for monothiohydrazidodiphosphonamides, where R, R', R'', R''', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #13:</u> Monothiodiphosphonamides, Bis(monothiodiphosphonamides), and	$(RR'-N)(R'')P(=S)-S-P(=O)(-R''')(-N-R''''R''''')$, or $(RR'-N)(R'')P(=S)-O-P(=O)(-R''')(-N-R''''R''''')$, where R, R', R'', R''', R''',

Poly(monothiodiphosphonamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #14:</u> Monothiodiphosphonic Acids, Bis(monothiodiphosphonic Acids), Poly(monothiodiphosphonic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(R-O-)(R'-)P(=S)-O-P(=O)(-R'')(-O-R'''); (R-O-)(R'-)P(=S)-S-P(=O)(-R'')(-O-R'''); (R-S-)(R'-)P(=S)-O-P(=O)(-R'')(-S-R'''); or (R-S-)(R'-)P(=S)-S-P(=O)(-R'')(-S-R'''), where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #15:</u> Monothioperoxydiphosphonamide, Bis(monothioperoxydiphosphonamide), and Poly(monothioperoxydiphosphonamide) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(RR'-N-)(R''-)P(=S)-S-S-P(=O)(-R''')(-N-R''''R'''''), where R, R', R'', R''', R'''', and R''''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #16:</u> Monothioperoxydiphosphonic Acids, Bis(monothioperoxydiphosphonic Acids), Poly(monothioperoxydiphosphonic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(R-O-)(R'-)P(=S)-S-S-P(=O)(-R''')(-O-R'''); or (R-S-)(R'-)P(=S)-S-S-P(=O)(-R''')(-S-R'''), where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #17:</u> Monothiophosphoric Acids (Phosphorothioic Acids), Bis(monothiophosphoric acids), Poly(monothiophosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	(O=)P(-S-R)(-O-R')(-O-R'') or (S=)P(-O-R)(-O-R')(-O-R''), where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #18:</u> Phosphoro(dithioperoxydic) Acids,	(O=)P(-S-S-R)(-O-R')(-O-R''), where R, R', and R'' represent H, NH ₂ or any organic

Bis[phosphoro(dithioperoxoic) acids], Poly[phosphoro(dithioperoxoic) acids], and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #19:</u> Monothiophosphonic Acids (Phosphonothioic Acids), Bis(monothiophosphonic Acids), Poly(monothiophosphonic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$(O=)PR(-S-R')(-O-R'')$ or $(S=)PR(-O-R')(-O-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #20:</u> Phosphono(dithioperoxoic) Acids, Bis[phosphono(dithioperoxoic) Acids], Poly[phosphono(dithioperoxoic) Acids], and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$(O=)PR(-S-S-R')(-O-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #21:</u> Beta-Hydroxythioketones, Beta-Hydroxythioaldehydes, Bis(beta-hydroxythioketones), Bis(beta-hydroxythioaldehydes), Poly(beta-hydroxythioketones), and Poly(beta-hydroxythioaldehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$R-CR'(-OH)-CH_2-C(=S)-R''$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #22:</u> Beta-Mercaptoketones, Beta-Mercaptoaldehydes, Bis(beta-mercaptoketones), Bis(beta-mercaptoaldehydes), Poly(beta-mercaptoketones), and Poly(beta-mercaptoaldehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$R-CR'(-SH)-CH_2-C(=O)-R''$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #23:</u> N-(Aminomethylol)thioureas [N-(Aminohydroxymethyl)thioureas], Bis[N-(aminomethylol)thioureas], and Poly[N-(aminomethylol)thioureas] (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$RR'-N-CH(-OH)-NR''-C(=S)-NR'''R''''$, where R, R', R'', R''', and R'''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

<p><u>S-O Valence Stabilizer #24:</u> N-(Aminomethylthiol)ureas [N-(Aminomercaptomethyl)ureas], Bis[N-(aminomethylthiol)ureas], and Poly[N-(aminomethylthiol)ureas] (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$RR'-N-CH(-SH)-NR''-C(=O)-NR'''R''''$, where R, R', R'', R''', and R'''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>S-O Valence Stabilizer #25:</u> Monothiooxamides, Bis(monothiooxamides), and Poly(monothiooxamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$RR'-N-C(=S)-C(=O)-N-R''R'''$, where R, R', R'', and R''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>S-O Valence Stabilizer #26:</u> Beta-Mercapto Carboxylic Acids, Bis(Beta-Mercapto Carboxylic Acids), Poly(Beta-Mercapto Carboxylic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$R-CR'(-SH)-CR''R'''-C(=O)(-O-R''''')$, where R, R', R'', R''', and R'''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>S-O Valence Stabilizer #27:</u> Beta-Mercapto Thiocarboxylic Acids, Bis(Beta-Mercapto Thiocarboxylic Acids), Poly(Beta-Mercapto Thiocarboxylic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$R-CR'(-SH)-CR''R'''-C(=O)(-S-R''''')$, where R, R', R'', R''', and R'''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>S-O Valence Stabilizer #28:</u> Beta-Hydroxy Thiocarboxylic Acids, Bis(Beta-Hydroxy Thiocarboxylic Acids), Poly(Beta-Hydroxy Thiocarboxylic Acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$R-CR'(-OH)-CR''R'''-C(=O)(-S-R''''')$, where R, R', R'', R''', and R'''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.</p>
<p><u>S-O Valence Stabilizer #29:</u> Beta-Mercapto Carboxamides, Bis(Beta-Mercapto Carboxamides), Poly(Beta-Mercapto Carboxamides), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)</p>	<p>$R-CR'(-SH)-CR''R'''-C(=O)(-NH-R''''')$, where R, R', R'', R''', and R'''' represent H, NH₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>

	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #30:</u> S-Alkylthiocarboxylic Acids, S-Arylthiocarboxylic Acids, and S,S-thiobiscarboxylic Acids (S-O Bidentates and S-O Tridentates)	R-S-R'COOH for S-alkylthiocarboxylic and S-arylthiocarboxylic acids, and HOOCR-S-R'COOH for S,S-thiobiscarboxylic acids, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #31:</u> S-Alkyldisulfidocarboxylic Acids, S-Aryldisulfidocarboxylic Acids, and S,S'-Disulfidobiscarboxylic Acids (S-O Bidentates and S-O Tridentates)	R-S-S-R'COOH for S-alkyldisulfidocarboxylic and S-aryldisulfidocarboxylic acids, and HOOCR-S-S-R'COOH for S,S'-disulfidobiscarboxylic acids, where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #32:</u> Monothiomonocarboxylic Acids, Dithiodicarboxylic Acids, Bis(monothiomonocarboxylic Acids), Bis(dithiodicarboxylic acids), Poly(monothiomonocarboxylic acids), Poly(dithiodicarboxylic acids), and derivatives thereof (S-O Bidentates and S-O Tetradentates)	R-C(=O)(-S-R') for monothiomonocarboxylic acids, and (R-S)(O=C-R'-C(=O)(-S-R'')) or (R-S)(O=C-R'-C(=O)(-O-R'')) for dithiodicarboxylic acids, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #33:</u> Monothiocarbonates and Bis(monothiocarbonates) (S-O Bidentates and S-O Tetradentates)	R-O-C(=S)-O-R', where R, and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #34:</u> Monothiocarbazates (Monothiocarbazides), Bis(monothiocarbazates), and Poly(monothiocarbazates) (S-O Bidentates, S-O Tridentates, and S-O Tetradentates; or possibly N-S Bidentates, N-S Tridentates,	RR'N-NR''-C(=O)(SH), where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.

and N-S Tetracentates)	Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #35:</u> Mercapto Alcohols and Silylmercaptoalcohols, Bis(mercapto alcohols and silylmercaptoalcohols), and Poly(mercapto alcohols and silylmercaptoalcohols) (S-O Bidentates, S- O Tridentates, S-O Tetracentates)	$R-CH(-SH)-CH(-OH)-R'$ for alpha-mercapto alcohols, $R-CH(-SH)-Si(-OR')_x-R''_{3-x}$ for alpha- silylmercaptoalcohols, $R-CH(-SH)-R'-CH(-OH)-R''$ for beta-mercapto alcohols, and $R-CH(-SH)-R'-Si(-OR'')_x-R'''_{3-x}$ for beta- silylmercaptoalcohols, etc., where R, R', R'', and R''' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. x = 1-3. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #36:</u> Monothiocarbimates, Bis(monothiocarbimates), and Poly(monothiocarbimates) (S-O Bidentates, S-O Tridentates, and S-O Tetracentates)	$RN=C(OH)(SH)$, where R represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #37:</u> Alkyl- and Aryl- Monothioborates and Bis(monothioborates) (S-O Bidentates and S-O Tetracentates)	$R-O-C(-S-R'')-O-R'$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #38:</u> Alkyl- and Aryl- Monothioboronates and Bis(monothioboronates) (S-O Bidentates and S-O Tetracentates)	$R-C(-S-R'')-O-R'$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water- insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-O Valence Stabilizer #39:</u> Monothioarsonic Acids (Arsonothioic Acids), Bis(monothioarsonic acids), Poly(monothioarsonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates)	$(O=)As(-S-R)(-O-R')(-O-R'')$ or $(S=)As(-O-R)(-O-R')(-O-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.

<p><u>S-O Valence Stabilizer #40:</u> Heterocyclic Rings containing One or Two Sulfur Atoms at least one additional Oxygen Atom Binding Site not in a Ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates)</p>	<p>Heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxy, carboxy, or carbonyl groups) that constitute O binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As or Se atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S-O Valence Stabilizer #41:</u> Heterocyclic Rings containing One or Two Oxygen Atoms at least one additional Sulfur Atom Binding Site not in a Ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates)</p>	<p>Heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional sulfur-containing substituents (usually thio, mercapto, or thiocarbonyl groups) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As or Se atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S-O Valence Stabilizer #42:</u> Heterocyclic Rings containing One or Two Sulfur Atoms at least one additional Oxygen Atom Binding Site in a separate Ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates)</p>	<p>Heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional oxygen-containing rings that constitute O binding sites. Can include other ring systems bound to the O-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As, or Se atoms. This 5-membered ring(s) and/or additional O-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.</p>
<p><u>S-O Valence Stabilizer #43:</u> Two-, Three-, Four-, Five-, Six-, Seven-, Eight-, Nine-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands,</p>	<p>Macrocyclic ligands containing two to ten sulfur or oxygen binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate</p>

Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur (usually thiol, mercapto, or thiocarbonyl groups) or Oxygen (hydroxy, carboxy, or carbonyl groups) and are not contained in Component Heterocyclic Rings (S-O Bidentates, S-O Tridentates, S-O Tetridentates, and S-O Hexadentates)	with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-O Valence Stabilizer #44:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur or Oxygen and are contained in Component 5-Membered Heterocyclic Rings (S-O Tridentates, S-O Tetridentates or S-O Hexadentates)	Macrocyclic ligands containing a total of four to ten five-membered heterocyclic rings containing sulfur or oxygen binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-O Valence Stabilizer #45:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur or Oxygen and are contained in a Combination of Heterocyclic Rings and Thiol, Mercapto, Thiocarbonyl, Hydroxy, Carboxy, and Carbonyl Groups (S-O Tridentates, S-O Tetridentates, or S-O Hexadentates)	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide sulfur or oxygen binding sites to valence stabilize the central metal ion. Other thiol, mercapto, thiocarbonyl, hydroxy, carboxy, or carbonyl binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four to ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-O Valence Stabilizer #46:</u> Sulfoxides (S-O Bidentates)	Sulfoxides (R-SO-R'), where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-O Valence Stabilizer #47:</u> Sulfones (S-O Bidentates)	Sulfones (R-SO ₂ -R'), where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.

S-O Valence Stabilizer #48: Sulfur dioxide (SO ₂) ligands (S-O Bidentates)	Sulfur dioxide ligands (-SO ₂) bound directly to the high valence metal ion.
N-P Valence Stabilizer #1: Aminoaryl Phosphines and Iminoaryl Phosphines (N-P Bidentates, N-P Tridentates, and N-P Tetracentates)	$[R(-NR'R'')(-PR'''R'''))]$, $[R(-NR'R'')]_x]_{1-3}P$, $[R(-NR'R'')]_x]_{1-3}PX$, or $[R(-PR'R'')]_x]_{1-3}N$, where X = O or S and R, R', R'', R''', and R''' represents H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
N-P Valence Stabilizer #2: Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms and having at least one additional Phosphorus Atom Binding Site not in a Ring (N-P Bidentates, N-P Tridentates, N-P Tetracentates, or N-P Hexacentates)	Five membered heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional phosphorus-containing substituents that constitute P binding sites. Can include other ring systems bound to the heterocyclic ring or to the P-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This ring(s) and/or attached, uncoordinating rings and/or P-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
N-P Valence Stabilizer #3: Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms and having at least one additional Nitrogen Atom Binding Site not in a Ring (N-P Bidentates, N-P Tridentates, N-P Tetracentates, or N-P Hexacentates)	Five membered heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional nitrogen-containing substituents (usually amines, imines, or hydrazides) that constitute N binding sites. Can include other ring systems bound to the heterocyclic ring or to the N-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This ring(s) and/or attached, uncoordinating rings and/or N-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
N-P Valence Stabilizer #4: Heterocyclic Rings containing One, Two, Three, or Four Nitrogen Atoms and having at least one additional Phosphorus Atom Binding Site in a Separate Ring (N-P Bidentates, N-P Tridentates, N-P Tetracentates)	Heterocyclic ring(s) containing one, two, three, or four nitrogen atoms. In addition, ligand contains additional phosphorus-containing rings that constitute P binding sites. Can include other ring systems bound to the N- or P-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence

	metal ion. Ring(s) can also contain O, S, or P atoms. This ring(s) and/or additional P-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-P Valence Stabilizer #5:</u> Two-, Three-, Four-, Five-, Six-, Seven-, Eight-, Nine-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen (usually amine or imine groups) or Phosphorus and are not contained in Component Heterocyclic Rings (N-P Bidentates, N-P Tridentates, N-P Tetradentates, and N-P Hexadentates)	Macrocyclic ligands containing two, three, four, five, six, seven, eight, nine, or ten binding sites composed of nitrogen and phosphorus to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>N-P Valence Stabilizer #6:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Phosphorus and are contained in Component Heterocyclic Rings (N-P Bidentates, N-P Tridentates, N-P Tetradentates, or N-P Hexadentates)	Macrocyclic ligands containing a total of four, five, six, seven, eight, nine, or ten heterocyclic rings containing nitrogen or phosphorus binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>N-P Valence Stabilizer #7:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Nitrogen or Phosphorus and are contained in a Combination of Heterocyclic Rings and Amine, Imine, and Phosphine Groups (N-P Bidentates, N-P Tridentates, N-P Tetradentates, or N-P Hexadentates)	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide nitrogen or phosphorus binding sites to valence stabilize the central metal ion. Other amine, imine, or phosphine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, five, six, seven, eight, nine, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-P Valence Stabilizer #1:</u> Thioaryl Phosphines (S-P Bidentates, S-P	$[R(-SR')_x]_{1-3}P$, $[R(-SR')_x]_{1-3}PX$, $[R(-PR'R'')(-SR''')]_x$, $[R(-PR'R'')(-S-S-R''')]_x$, $[R(-PR'R'')(-$

Tridentates, and S-P Tetridentates)	$C(=S)R'''$, $[R(-PR'R'')]_xS$, $[R(-PR'R'')]_x]_2-3R'''(-SR''')$, $[R(-SR')_x]_2-3R'''(-PR'''R''')$, $[R(-PR'R'')]_x]_2S_2$, and $[R(-PR'R'')]_x]_2R'''(C(=S))_yR''''$, where X = O or S, and R, R', R'', R''', and R'''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and x = 1-2 and y = 1-4. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>S-P Valence Stabilizer #2:</u> Heterocyclic Rings containing One or Two Sulfur Atoms and having at least one additional Phosphorus Atom Binding Site not in a Ring (P-S Bidentates, P-S Tridentates, P-S Tetridentates, or P-S Hexadentates)	Heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional phosphorus-containing substituents that constitute P binding sites. Can include other ring systems bound to the heterocyclic ring or to the P-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This ring(s) and/or attached, uncoordinating rings and/or P-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-P Valence Stabilizer #3:</u> Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms and having at least one additional Sulfur Atom Binding Site not in a Ring (S-P Bidentates, S-P Tridentates, S-P Tetridentates, or S-P Hexadentates)	Heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional sulfur-containing substituents (usually thiol, mercapto, or thiocarbonyl groups) that constitute S binding sites. Can include other ring systems bound to the heterocyclic ring or to the S-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This ring(s) and/or attached, uncoordinating rings and/or S-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-P Valence Stabilizer #4:</u> Heterocyclic Rings containing One or Two Sulfur Atoms and having at least one additional Phosphorus Atom Binding Site in a Separate Ring (S-P Bidentates, S-P Tridentates, S-P Tetridentates)	Heterocyclic ring(s) containing one or two sulfur atoms. In addition, ligand contains additional phosphorus-containing rings that constitute P binding sites. Can include other ring systems bound to the S- or P-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S, or P atoms. This

	ring(s) and/or additional P-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-P Valence Stabilizer #5:</u> Two-, Three-, Four-, Five-, Six-, Seven-, Eight-, Nine-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur (usually thiol, mercapto, or thiocarbonyl groups) or Phosphorus and are not contained in Component Heterocyclic Rings (S-P Bidentates, S-P Tridentates, S-P Tetridentates, and S-P Hexadentates)	Macrocyclic ligands containing two, three, four, five, six, seven, eight, nine, or ten binding sites composed of sulfur and phosphorus to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>S-P Valence Stabilizer #6:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur or Phosphorus and are contained in Component Heterocyclic Rings (S-P Bidentates, S-P Tridentates, S-P Tetridentates, or S-P Hexadentates)	Macrocyclic ligands containing a total of four, five, six, seven, eight, nine, or ten heterocyclic rings containing sulfur or phosphorus binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>S-P Valence Stabilizer #7:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Sulfur or Phosphorus and are contained in a Combination of Heterocyclic Rings and Thiol, Mercapto, Thiocarbonyl or Phosphine Groups (S-P Bidentates, S-P Tridentates, S-P Tetridentates, or S-P Hexadentates)	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide sulfur or phosphorus binding sites to valence stabilize the central metal ion. Other thiol, mercapto, or thiocarbonyl, or phosphine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, five, six, seven, eight, nine, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>P-O Valence Stabilizer #1:</u> Hydroxyaryl Phosphines (P-O Bidentates, P-O Tridentates, and P-O Tetridentates)	$[R(-OR')_x]_{1-3}P$, $[R(-OR')_x]_{1-3}PX$, $[R(-PR'R'')(-OR''')]$, $[R(-PR'R'')(-C(=O)R''')]$, $[R(-PR'R'')_x]_2O$, $[R(-PR'R'')_x]_{2-3}R'''(-OR''')$, $[R(-$

	$\text{OR}')_x]_{2-3}\text{R}''(-\text{PR}'''\text{R}''''')_y$, and $[\text{R}(-\text{PR}'\text{R}'')_x]_2\text{R}'''(\text{C}(=\text{O}))_y\text{R}''''$, where $X = \text{O}$ or S , and $\text{R}, \text{R}', \text{R}'', \text{R}'''$, and R'''' represent H, NH_2 , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached, and $x = 1-2$ and $y = 1-4$. Ligand can also contain nonbinding $\text{N}, \text{O}, \text{S}$, or P atoms.
<u>P-O Valence Stabilizer #2:</u> Heterocyclic Rings containing One or Two Oxygen Atoms and having at least one additional Phosphorus Atom Binding Site not in a Ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates, or P-O Hexacentates)	Heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional phosphorus-containing substituents that constitute P binding sites. Can include other ring systems bound to the heterocyclic ring or to the P-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S , or P atoms. This ring(s) and/or attached, uncoordinating rings and/or P-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P-O Valence Stabilizer #3:</u> Heterocyclic Rings containing One, Two, or Three Phosphorus Atoms and having at least one additional Oxygen Atom Binding Site not in a Ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates, or P-O Hexacentates)	Heterocyclic ring(s) containing one, two, or three phosphorus atoms. In addition, ligand contains additional oxygen-containing substituents (usually hydroxy, carboxy, or carbonyl groups) that constitute O binding sites. Can include other ring systems bound to the heterocyclic ring or to the O-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S , or P atoms. This ring(s) and/or attached, uncoordinating rings and/or O-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P-O Valence Stabilizer #4:</u> Heterocyclic Rings containing One or Two Oxygen Atoms at least one additional Phosphorus Atom Binding Site in a Separate Ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates)	Heterocyclic ring(s) containing one or two oxygen atoms. In addition, ligand contains additional phosphorus-containing rings that constitute P binding sites. Can include other ring systems bound to the O- or P-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, S , or P atoms. This ring(s) and/or additional P-containing ring(s) and/or attached, uncoordinating rings may or

	may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P-O Valence Stabilizer #5:</u> Two-, Three-, Four-, Five-, Six-, Seven-, Eight-, Nine-, and Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen (usually hydroxy, carboxy, or carbonyl groups) or Phosphorus and are not contained in Component Heterocyclic Rings (P-O Bidentates, P-O Tridentates, P-O Tetradentates, and P-O Hexadentates)	Macrocyclic ligands containing two, three, four, five, six, seven, eight, nine, or ten binding sites composed of oxygen and phosphorus to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>P-O Valence Stabilizer #6:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen or Phosphorus and are contained in Component Heterocyclic Rings (P-O Bidentates, P-O Tridentates, P-O Tetradentates, or P-O Hexadentates)	Macrocyclic ligands containing a total of four, five, six, seven, eight, nine, or ten heterocyclic rings containing oxygen or phosphorus binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>P-O Valence Stabilizer #7:</u> Four-, Five-, Six-, Seven-, Eight-, Nine-, or Ten-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Oxygen or Phosphorus and are contained in a Combination of Heterocyclic Rings and Hydroxy, Carboxy, Carbonyl or Phosphine Groups (P-O Bidentates, P-O Tridentates, P-O Tetradentates, or P-O Hexadentates)	Macrocyclic ligands containing at least one heterocyclic ring. These heterocyclic rings provide oxygen or phosphorus binding sites to valence stabilize the central metal ion. Other hydroxy, carboxy, carbonyl, or phosphine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four, five, six, seven, eight, nine, or ten. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>As Valence Stabilizer #1:</u> Monoarsines (As Monodentates) wherein at least one Arsenic Atom is a Binding Site	AsH ₃ , AsH ₂ R, AsHR ₂ , where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups

	attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #2:</u> Diarsines (an As-As Bidentate) wherein at least one Arsenic Atom is a Binding Site	R'-As-R-As-R'', where R, R', and R'' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #3:</u> Triarsines (either As-As Bidentates or As-As Tridentates) wherein at least one Arsenic Atom is a Binding Site	R-As-R'-As-R''-As-R''', where R, R', R'', and R''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #4:</u> Tetraarsines (As-As Bidentates, As-As Tridentates, or As-As Tetracentates) wherein at least one Arsenic Atom is a Binding Site	R-As-R'-As-R''-As-R'''-As-R''''-As-R''''', where R, R', R'', R''', and R'''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #5:</u> Pentaarsines (As-As Bidentates, As-As Tridentates, or As-As Tetracentates) wherein at least one Arsenic Atom is a Binding Site	R-As-R'-As-R''-As-R'''-As-R''''-As-R''''', where R, R', R'', R''', R'''', and R''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #6:</u> Hexaarsines (As-As Bidentates, As-As Tridentates, As-As Tetracentates, or As-As Hexadentates) wherein at least one Arsenic Atom is a Binding Site	R-As-R'-As-R''-As-R'''-As-R''''-As-R'''''-As-R''''''-As-R''''''', where R, R', R'', R''', R'''', R''''', and R'''''' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, As, O, S, or Se atoms.
<u>As Valence Stabilizer #7:</u> Five-Membered Heterocyclic Rings containing One Arsenic Atom wherein the Arsenic Atom is the Binding Site (As Monodentates)	Five membered heterocyclic ring containing just one arsenic binding site. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S,

	N, P, or Se atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #8:</u> Six-Membered Heterocyclic Rings containing One Arsenic Atom wherein the Arsenic Atom is the Binding Site (As Monodentates)	Six membered heterocyclic ring containing just one arsenic binding site. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, S, N, P, or Se atoms. This 6-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #9:</u> Five-Membered Heterocyclic Rings containing One Arsenic Atom and having at least one additional Arsenic Atom Binding Site not in a Ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetradentates, or As-As Hexadentates)	Five membered heterocyclic ring(s) containing one arsenic atom. In addition, ligand contains additional arsenic-containing substituents (usually arsines) that constitute As binding sites. Can include other ring systems bound to the heterocyclic ring or to the As-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, P or Se atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or As-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #10:</u> Six-Membered Heterocyclic Rings containing One Arsenic Atom and having at least one additional Arsenic Atom Binding Site not in a Ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetradentates, or As-As Hexadentates)	Six membered heterocyclic ring(s) containing one arsenic atom. In addition, ligand contains additional arsenic-containing substituents (usually arsines) that constitute As binding sites. Can include other ring systems bound to the heterocyclic ring or to the As-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, P or Se atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or As-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #11:</u> Five-Membered Heterocyclic Rings containing One Arsenic Atom and having at least one additional Arsenic Atom Binding Site in a separate Ring (As Monodentates,	Five membered heterocyclic ring(s) containing one arsenic atom. In addition, ligand contains additional arsenic-containing rings that constitute As binding sites. Can include other ring systems bound to the As-containing

As-As Bidentates, As-As Tridentates, As-As Tetridentates, or As-As Hexadentates)	heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, P, or Se atoms. This 5-membered ring(s) and/or additional As-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #12:</u> Six-Membered Heterocyclic Rings containing One Arsenic Atom and having at least one additional Arsenic Atom Binding Site in a separate Ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetridentates, or As-As Hexadentates)	Six membered heterocyclic ring(s) containing one arsenic atom. In addition, ligand contains additional arsenic-containing rings that constitute As binding sites. Can include other ring systems bound to the As-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, S, P, or Se atoms. This 6-membered ring(s) and/or additional As-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #13:</u> Two-, Three-, Four-, and Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Arsenic and are not contained in Component Heterocyclic Rings (As-As Bidentates, As-As Tridentates, As-As Tetridentates, and As-As Hexadentates)	Macrocyclic ligands containing two, three, four, or six arsenic binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>As Valence Stabilizer #14:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Arsenic and are contained in Component 5-Membered Heterocyclic Rings (As-As Tridentates, As-As Tetridentates, or As-As Hexadentates)	Macrocyclic ligands containing a total of four or six five-membered heterocyclic rings containing arsenic binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>As Valence Stabilizer #15:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide arsenic binding sites to valence stabilize the central metal ion. Other arsine binding sites can also be included in the

Binding Sites are composed of Arsenic and are contained in a Combination of 5-Membered Heterocyclic Rings and Arsine Groups (As-As Tridentates, As-As Tetracentates, or As-As Hexacentates)	macrocyclic ligand, so long as the total number of binding sites is four or eight. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>As Valence Stabilizer #16:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Arsenic and are contained in Component 6-Membered Heterocyclic Rings (As-As Tridentates, As-As Tetracentates, or As-As Hexacentates)	Macrocyclic ligands containing a total of four or six six-membered heterocyclic rings containing arsenic binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>As Valence Stabilizer #17:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Arsenic and are contained in a Combination of 6-Membered Heterocyclic Rings and Arsine Groups (As-As Tridentates, As-As Tetracentates, or As-As Hexacentates)	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These heterocyclic rings provide arsenic binding sites to valence stabilize the central metal ion. Other arsine binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four or six. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>Se Valence Stabilizer #1:</u> Monoselenoethers (Se Monodentates) wherein at least one Selenium Atom is a Binding Site	SeH_2 , SeHR , SeR_2 , where R represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>Se Valence Stabilizer #2:</u> Diselenoethers (Se-Se Bidentates) wherein at least one Selenium Atom is a Binding Site	R-Se-R'-Se-R'' , where R, R', and R'' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N,

	P, O, S, or Se atoms.
<u>Se Valence Stabilizer #3:</u> Triselenoethers (Se-Se Bidentates or Se-Se Tridentates) wherein at least one Selenium Atom is a Binding Site	R-Se-R'-Se-R''-Se-R''', where R, R', R'', and R''' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>Se Valence Stabilizer #4:</u> Tetraselenoethers (Se-Se Bidentates, Se-Se Tridentates, or Se-Se Tetracentates) wherein at least one Selenium Atom is a Binding Site	R-Se-R'-Se-R''-Se-R'''-Se-R''''', where R, R', R'', R''', and R'''' represents H or any organic functional group wherein the number of carbon atoms ranges from 0 to 25, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, P, O, S, or Se atoms.
<u>Se Valence Stabilizer #5:</u> Five-Membered Heterocyclic Rings containing One or Two Selenium Atoms wherein at least one Selenium Atom is a Binding Site (Se Monodentates or Se-Se Bidentates)	Five membered heterocyclic ring containing one or two selenium atoms, both of which may function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, N, P, As, or S atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #6:</u> Six-Membered Heterocyclic Rings containing One or Two Selenium Atoms wherein at least one Selenium Atom is a Binding Site (Se Monodentates or Se-Se Bidentates)	Six membered heterocyclic ring containing one or two selenium atoms, both of which may function as binding sites. Can include other ring systems bound to this heterocyclic ring, but they do not coordinate with the stabilized, high valence metal ion. Ring can also contain O, N, P, As, or S atoms. This 5-membered ring and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #7:</u> Five-Membered Heterocyclic Rings containing One Selenium Atom and having at least one additional Selenium Atom Binding Site not in a Ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexadentates)	Five membered heterocyclic ring(s) containing one selenium atom. In addition, ligand contains additional selenium-containing substituents (usually selenols or selenoethers) that constitute Se binding sites. Can include other ring systems bound to the heterocyclic ring or to the Se-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As

	or S atoms. This 5-membered ring(s) and/or attached, uncoordinating rings and/or Se-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #8:</u> Six-Membered Heterocyclic Rings containing One Selenium Atom and having at least one additional Selenium Atom Binding Site not in a Ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexadentates)	Six membered heterocyclic ring(s) containing one selenium atom. In addition, ligand contains additional selenium-containing substituents (usually selenols or selenoethers) that constitute Se binding sites. Can include other ring systems bound to the heterocyclic ring or to the Se-containing substituent, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As or S atoms. This 6-membered ring(s) and/or attached, uncoordinating rings and/or Se-containing substituent(s) may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #9:</u> Five-Membered Heterocyclic Rings containing One Selenium Atom and having at least one additional Selenium Atom Binding Site in a separate Ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexadentates)	Five membered heterocyclic ring(s) containing one selenium atom. In addition, ligand contains additional selenium-containing rings that constitute Se binding sites. Can include other ring systems bound to the Se-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As, or S atoms. This 5-membered ring(s) and/or additional Se-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #10:</u> Six-Membered Heterocyclic Rings containing One Selenium Atom and having at least one additional Selenium Atom Binding Site in a separate Ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexadentates)	Six membered heterocyclic ring(s) containing one selenium atom. In addition, ligand contains additional selenium-containing rings that constitute Se binding sites. Can include other ring systems bound to the Se-containing heterocyclic rings, but they do not coordinate with the stabilized, high valence metal ion. Ring(s) can also contain O, N, P, As, or S atoms. This 6-membered ring(s) and/or additional Se-containing ring(s) and/or attached, uncoordinating rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #11:</u>	Macrocyclic ligands containing two, three, four,

Two-, Three-, Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Selenium (usually selenol or selenoether groups) and are not contained in Component Heterocyclic Rings (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetradentates, or Se-Se Hexadentates)	or six selenium binding sites to valence stabilize the central metal ion. Can include other hydrocarbon or ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbons/rings may or may not have halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Se Valence Stabilizer #12:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Selenium and are contained in Component 5-Membered Heterocyclic Rings (Se-Se Tridentates, Se-Se Tetradentates or Se-Se Hexadentates)	Macrocyclic ligands containing a total of four or six five-membered heterocyclic rings containing selenium binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>Se Valence Stabilizer #13:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Selenium and are contained in a Combination of 5-Membered Heterocyclic Rings and Selenol or Selenoether Groups (Se-Se Tridentates, Se-Se Tetradentates, or Se-Se Hexadentates)	Macrocyclic ligands containing at least one 5-membered heterocyclic ring. These heterocyclic rings provide selenium binding sites to valence stabilize the central metal ion. Other selenol or selenoether binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four or six. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>Se Valence Stabilizer #14:</u> Four-, or Six-Membered Macrocyclics, Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Selenium and are contained in Component 6-Membered Heterocyclic Rings (Se-Se Tridentates, Se-Se Tetradentates, or Se-Se Hexadentates)	Macrocyclic ligands containing a total of four or six six-membered heterocyclic rings containing selenium binding sites. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>Se Valence Stabilizer #15:</u> Four-, or Six-Membered Macrocyclics,	Macrocyclic ligands containing at least one 6-membered heterocyclic ring. These

Macrobicyclics, and Macropolycyclics (including Catapinands, Cryptands, Cyclidenes, and Sepulchrates) wherein all Binding Sites are composed of Selenium and are contained in a Combination of 6-Membered Heterocyclic Rings and Selenol or Selenoether Groups (Se-Se Tridentates, Se-Se Tetridentates, or Se-Se Hexadentates)	heterocyclic rings provide selenium binding sites to valence stabilize the central metal ion. Other selenol or selenoether binding sites can also be included in the macrocyclic ligand, so long as the total number of binding sites is four or six. Can include other hydrocarbon/ring systems bound to this macrocyclic ligand, but they do not coordinate with the stabilized, high valence metal ion. This ligand and/or attached, uncoordinating hydrocarbon/rings may or may not have halogen or polarizing or water-insolubilizing groups attached.
<u>Se Valence Stabilizer #16:</u> 1,3-Diselenoketones (Diseleno-beta-ketonates), 1,3,5-Triselenoketones, Bis(1,3-Diselenoketones), and Poly(1,3-Diselenoketones) (S-S Bidentates, S-S Tridentates, S-S Tetridentates)	$R-C(=Se)-CR'R''-C(=Se)-R'''$ where R, R', R'', and R''' represent H, NH ₂ , or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #17:</u> 1,1-Diselenolates, Bis(1,1-diselenolates), and Poly(1,1-diselenolates) (Se-Se Bidentates and Se-Se Tetridentates)	$RR'-C=C(-Se^-)(-Se^-)$, where R and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #18:</u> Diselenocarbamates, Bis(diselenocarbamates), and Poly(diselenocarbamates) (including N-hydroxydiselenocarbamates and N-mercaptodiselenocarbamates) (Se-Se Bidentates, Se-Se Tridentates, and Se-Se Tetridentates)	$RR'N^+=C(SeH)(SeH)$, where R and R' represent H, OH, SH, OR'' (R'' = C ₁ -C ₃₀ alkyl or aryl), SR'' (R'' = C ₁ -C ₃₀ alkyl or aryl), NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #19:</u> Triselenophosphoric Acids (Phosphorotriselenoic Acids), Bis(triselenophosphoric acids), Poly(triselenophosphoric acids), and derivatives thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetridentates)	$(O=P(-Se-R)(-Se-R')(-Se-R''))$ or $(Se=P(-Se-R)(-Se-R')(-O-R''))$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #20:</u>	$(O=P(-Se-R)(-Se-R')(-O-R''))$ or $(Se=P(-Se-$

Diselenophosphoric Acids (Phosphorodiselenoic Acids), Bis(diselenophosphoric acids), Poly(diselenophosphoric acids), and derivatives thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates)	$R(-O-R')(-O-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #21:</u> Tetraselenophosphoric Acids (Phosphorotetraselenoic Acids), Bis(tetraselenophosphoric acids), Poly(tetraselenophosphoric acids), and derivatives thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates)	$(Se=P)(-Se-R)(-Se-R')(-Se-R'')$, where R, R', and R'' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #22:</u> Diselenocarbonates, Triselenocarbonates, Bis(diselenocarbonates), and Bis(triselenocarbonates), (Se-Se Bidentates and Se-Se Tetracentates)	$R-Se-C(=Se)-O-R'$ or $R-Se-C(=O)-Se-R'$ for diselenocarbonates, and $R-Se-C(=Se)-Se-R'$ for triselenocarbonates, where R, and R' represent H, NH ₂ or any organic functional group wherein the number of carbon atoms ranges from 0 to 40, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached. Ligand can also contain nonbinding N, O, S, or P atoms.
<u>Se Valence Stabilizer #23:</u> Selenocyanates (Se Monodentates)	Selenocyanates bound directly to the high valence metal ion.
<u>Se Valence Stabilizer #24:</u> Selenolates (Se Monodentates)	Selenolates (HSe-R, HSe-R-SeH, etc.), where R and R' represent H or any organic functional group wherein the number of carbon atoms ranges from 0 to 35, optionally having halogen or polarizing or water-insolubilizing/solubilizing groups attached.
<u>Miscellaneous Valence Stabilizer #1:</u> Diene or bicyclic or tricyclic hydrocarbon ligands	Dialkenes or bicyclic or tricyclic hydrocarbons bound directly to the high valence metal ion.
<u>Miscellaneous Valence Stabilizer #2:</u> Cyanide and related ligands	Cyanide and cyanate and related ligands bound directly to the high valence metal ion.
<u>Miscellaneous Valence Stabilizer #3:</u> Carbonyl ligands	Carbonyl (-CO) ligands bound directly to the high valence metal ion.
<u>Miscellaneous Valence Stabilizer #4:</u> Halogen ligands	Halogen (X) atoms bound directly to the high valence metal ion.
<u>Miscellaneous Valence Stabilizer #5:</u> Hydroxo and Oxo Ligands	Hydroxo and oxo ligands bound directly to the high valence metal ion.

N Valence Stabilizer #1a: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates or N-N Tetracentates) that meet the requirements

- 5 for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
pentaazacyclodecane ([10]aneN₅); pentaazacycloundecane ([11]aneN₅); pentaazacyclododecane ([12]aneN₅); pentaazacyclotridecane ([13]aneN₅); pentaazacyclotetradecane ([14]aneN₅);
pentaazacyclopentadecane ([15]aneN₅); pentaazacyclodecatriene ([10]trieneN₅);
pentaazacycloundecatriene ([11]trieneN₅); pentaazacyclododecatriene ([12]trieneN₅);
10 pentaazacyclotridecatriene ([13]trieneN₅); pentaazacyclotetradecatriene ([14]trieneN₅); and
pentaazacyclopentadecatriene ([15]trieneN₅).

N Valence Stabilizer #1b: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
15 binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: heptaazacyclotetradecane ([14]aneN₇); heptaazacyclopentadecane ([15]aneN₇);
heptaazacyclohexadecane ([16]aneN₇); heptaazacycloheptadecane ([17]aneN₇);

- 20 heptaazacyclooctadecane ([18]aneN₇); heptaazacyclononadecane ([19]aneN₇);
heptaazacycloeicosane ([20]aneN₇); heptaazacycloheneicosane ([21]aneN₇);
heptaazacyclotetradecatriene ([14]trieneN₇); heptaazacyclopentadecatriene ([15]trieneN₇);
heptaazacyclohexadecatriene ([16]trieneN₇); heptaazacycloheptadecatriene ([17]trieneN₇);
heptaazacyclooctadecatriene ([18]trieneN₇); heptaazacyclononadecatriene ([19]trieneN₇);
25 heptaazacycloeicosatriene ([20]trieneN₇); and heptaazacycloheneicosatriene ([21]trieneN₇).

N Valence Stabilizer #1c: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
30 binding sites are composed of nitrogen (usually amine or imine groups) and are not contained in component heterocyclic rings (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not

- limited to: nonaazacyclooctadecane ([18]aneN₉); nonaazacyclononadecane ([19]aneN₉); nonaazacycloeicosane ([20]aneN₉); nonaazacycloheneicosane ([21]aneN₉); nonaazacyclodocosane ([22]aneN₉); nonaazacyclotricosane ([23]aneN₉); nonaazacyclotetracosane ([24]aneN₉); nonaazacyclopentacosane ([25]aneN₉);
- 5 nonaazacyclohexacosane ([26]aneN₉); nonaazacycloheptacosane ([27]aneN₉); nonaazacyclooctadecatetradene ([18]tetradeneN₉); nonaazacyclononadecatetradene ([19]tetradeneN₉); nonaazacycloeicosatetradene ([20]tetradeneN₉); nonaazacycloheneicosatetradene ([21]tetradeneN₉); nonaazacyclodocosatetradene ([22]tetradeneN₉); nonaazacyclotricosatetradene ([23]tetradeneN₉);
- 10 nonaazacyclotetracosatetradene ([24]tetradeneN₉); nonaazacyclopentacosatetradene ([25]tetradeneN₉); nonaazacyclohexacosatetradene ([26]tetradeneN₉); and nonaazacycloheptacosatetradene ([27]tetradeneN₉).

- N Valence Stabilizer #2a: Examples of five-membered macrocyclics, macrobicyclics, and
- 15 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all five binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: pentaphyrins (pentapyrroles); sapphyrins; smaragdyrins; pentaoxazoles; pentaisooxazoles; pentathiazoles; pentaisothiazoles;
- 20 pentaazaphospholes; pentaimidazoles; pentapyrazoles; pentaoxidiazoles; pentathiadiazoles; pentadiazaphospholes; pentatriazoles; pentaoxidiazoles; and pentathiatriazoles.

- N Valence Stabilizer #2b: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
- 25 seven binding sites are composed of nitrogen and are contained in component 5-membered heterocyclic rings (N-N Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: heptaphyrins (heptapyrroles); heptaoxazoles; heptaisooxazoles; heptathiazoles; heptaisothiazoles; heptaazaphospholes; heptaimidazoles; heptapyrazoles; heptaoxidiazoles; heptathiadiazoles; heptadiazaphospholes;
- 30 heptatriazoles; heptaoxidiazoles; and heptathiatriazoles.

N Valence Stabilizer #3a: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all five binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates or N-N Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: superphthalocyanine; supernaphthalocyanine; diazapentaphyrins; tetraazapentaphyrins; pentaazapentaphyrins; diazapentapyrazoles; tetraazapentapyrazoles; pentaazapentapyrazoles; diazapentaimidazoles; tetraazapentaimidazoles; and pentaazapentaimidazoles.

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N Valence Stabilizer #3b: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all seven binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diazaheptaphyrins; tetraazaheptaphyrins; hexaazaheptaphyrins; diazaheptapyrazoles; tetraazaheptapyrazoles; hexaazaheptapyrazoles; diazaheptaimidazoles; tetraazaheptaimidazoles; and hexaazaheptaimidazoles.

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N Valence Stabilizer #3c: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all nine binding sites are composed of nitrogen and are contained in a combination of 5-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetracentates, or N-N Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diazanonaphyrins; tetraazanonaphyrins; hexaazanonaphyrins; diazanonapyrazoles; tetraazanonapyrazoles; hexaazanonapyrazoles; diazanonaimidazoles; tetraazanonaimidazoles; and hexaazanonaimidazoles.

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N Valence Stabilizer #4a: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all five binding sites are composed of nitrogen and are contained in component 6-membered

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heterocyclic rings (N-N Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclopentapyridines; cyclopentaoxazines; cyclopentathiazines; cyclopentaphosphorins; cyclopentaquinolines; cyclopentapyrazines; cyclopentapyridazines; cyclopentapyrimidines; cyclopentaoxadiazines;

5 cyclopentathiadiazines; cyclopentadiazaphosphorins cyclopentaquinoxalines; cyclopentatriazines; cyclopentathiatriazines; and cyclopentaoxatriazines.

N Valence Stabilizer #4b: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

10 seven binding sites are composed of nitrogen and are contained in component 6-membered heterocyclic rings (N-N Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cycloheptapyridines; cycloheptaoxazines; cycloheptathiazines; cycloheptaphosphorins; cycloheptaquinolines; cycloheptapyrazines; cycloheptapyridazines; cycloheptapyrimidines; cycloheptaoxadiazines;

15 cycloheptathiadiazines; cycloheptadiazaphosphorins cycloheptaquinoxalines; cycloheptatriazines; cycloheptathiatriazines; and cycloheptaoxatriazines.

N Valence Stabilizer #5a: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

20 five binding sites are composed of nitrogen and are contained in a combination of 6-membered heterocyclic rings and amine or imine groups (N-N Tridentates or N-N Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclopentapyridines; tetraazacyclopentapyridines; diazacyclopentaquinolines; tetraazacyclopentaquinolines; diazacyclopentapyrazines; tetraazacyclopentapyrazines;

25 diazacyclopentapyridazines; tetraazacyclopentapyridazines; diazacyclopentapyrimidines; tetraazacyclopentapyrimidines; diazacyclopentatriazines; and tetraazacyclopentatriazines.

N Valence Stabilizer #5b: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

30 seven binding sites are composed of nitrogen and are contained in a combination of 6-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetridentates, or N-N

Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacycloheptapyridines; tetraazacycloheptapyridines; diazacycloheptaquinolines; tetraazacycloheptaquinolines; diazacycloheptapyrazines; tetraazacycloheptapyrazines; diazacycloheptapyridazines; tetraazacycloheptapyridazines; 5 diazacycloheptapyrimidines; tetraazacycloheptapyrimidines; diazacycloheptatriazines; and tetraazacycloheptatriazines.

N Valence Stabilizer #5c: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all 10 nine binding sites are composed of nitrogen and are contained in a combination of 6-membered heterocyclic rings and amine or imine groups (N-N Tridentates, N-N Tetracentates, or N-N Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diazacyclononapyridines; tetraazacyclononapyridines; diazacyclononaquinolines; tetraazacyclononaquinolines; diazacyclononapyrazines; 15 tetraazacyclononapyrazines; diazacyclononapyridazines; tetraazacyclononapyridazines; diazacyclononapyrimidines; tetraazacyclononapyrimidines; diazacyclononatriazines; and tetraazacyclononatriazines.

N Valence Stabilizer #6: Examples of silylamines and silazanes (N Monodentates, N-N Bidentates, N-N Tridentates, N-N Tetracentates, and N-N Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trisilylamine; N-methyldisilazane (disilylmethylamine); N,N-dimethylsilylamine; (silyldimethylamine); tris(trimethylsilyl)amine; triethylsilylamine (triethylaminosilane) (triethylsilazane); N-ethyltriethylsilylamine (triethyl-N-ethylaminosilane); di-tert- 25 butylsilanedi-amine (di-tert-butyl-diaminosilane); bis(methylamino)diethylsilane; tris(dimethylamino)ethylsilane; hexamethyldisilazane; N-methylhexaphenyldisilazane; hexamethylcyclotrisilazane; and octaphenylcyclotetrasilazane. [Note: silylamines and silazanes are notably weaker ligands than their carbonaceous derivatives, although replacement of one or two SiR_3 groups with CR_3 will enhance the donor power of the ligand. Thus, $N(CR_3)_2(SiR_3)$ is a 30 better ligand than $N(CR_3)(SiR_3)_2$, etc.]

N Valence Stabilizer #7: Examples of guanidines, diguanidines, and polyguanidines (N-N bidentates, N-N tridentates, N-N tetradentates, and N-N hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: guanidine; methylguanidine; ethylguanidine; isopropylguanidine; butylguanidine; benzylguanidine;

- 5 phenylguanidine; tolylguanidine; naphthylguanidine; cyclohexylguanidine; norbornylguanidine; adamantylguanidine; dimethylguanidine; diethylguanidine; diisopropylguanidine; dibutylguanidine; dibenzylguanidine; diphenylguanidine; ditolylguanidine; dinaphthylguanidine; dicyclohexylguanidine; dinorbornylguanidine; diadamantylguanidine; ethylenediguanidine; propylenediguanidine; tetramethylenediguanidine; pentamethylenediguanidine;
- 10 hexamethylenediguanidine; heptamethylenediguanidine; octamethylenediguanidine; phenylenediguanidine; piperazinediguanidine; oxalyldiguanidine; malonyldiguanidine; succinyldiguanidine; glutaryldiguanidine; adipyldiguanidine; pimelyldiguanidine; suberyldiguanidine; phthalalydiguanidine; benzimidazoleguanidine; aminoguanidine; nitroaminoguanidine; dicyandiamide (cyanoguanidine); dodecylguanidine; and nitrovin.

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N Valence Stabilizer #8: Examples of phosphonitrile amides and bis(phosphonitrile amides) (N-N Bidentates and N-N Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonitrile amide; N-phenylphosphonitrile amide; N-benzylphosphonitrile amide; N-cyclohexylphosphonitrile amide;

20 N-norbornylphosphonitrile amide; N,N'-diphenylphosphonitrile amide; N,N'-dibenzylphosphonitrile amide; N,N'-dicyclohexylphosphonitrile amide; and N,N'-dinorbornylphosphonitrile amide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizaton of high valence metal ions much more difficult, though still possible.]

- 25 N Valence Stabilizer #9: Examples of phosphonimidic diamides, bis(phosphonimidic diamides), and poly(phosphonimidic diamides) (N-N bidentates and N-N tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonimidic diamide; N-benzylphosphonimidic diamide; N-phenylphosphonimidic diamide; N-cyclohexylphosphonimidic diamide; N-norbornylphosphonimidic diamide; N,N-
- 30 dibenzylphosphonimidic diamide; N,N-diphenylphosphonimidic diamide; N,N-dicyclohexylphosphonimidic diamide; and N,N-dinorbornylphosphonimidic diamide. [Note: the

phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

N Valence Stabilizer #10: Examples of phosphonamidimidic acid, phosphonamidimidothioic

- 5 acid, bis(phosphonamidimidic acid), bis(phosphonamidimidothioic acid),
poly(phosphonamidimidic acid), poly(phosphonamidimidothioic acid), and derivatives thereof
(N-N Bidentates, and N-N Tetradentates) that meet the requirements for use as “narrow band”
valence stabilizers for Ce^{+4} include, but are not limited to: phosphonamidimidic acid,
phosphonamidimidothioic acid; O-phenylphosphonamidimidic acid; O-
10 benzylphosphonamidimidic acid; O-cyclohexylphosphonamidimidic acid; O-
norbornylphosphonamidimidic acid; S-phenylphosphonamidimidothioic acid; S-
benzylphosphonamidimidothioic acid; S-cyclohexylphosphonamidimidothioic acid; and S-
norbornylphosphonamidimidothioic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus
atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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N Valence Stabilizer #11: Examples of pyridinaldimines, bis(pyridinaldimines), and
poly(pyridinaldimines) (N-N Bidentates, N-N Tridentates, and N-N Tetradentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
pyridylideneaniline [N-(pyridylmethylene)benzenamine]; and (2-pyridyl)benzylideneaniline.

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N Valence Stabilizer #12: Examples of hydrazones, bis(hydrazones), and poly(hydrazones) (N
Monodentates, N-N Bidentates, N-N Tridentates, and N-N Tetradentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
acetaldehyde hydrazone; acetaldehyde phenylhydrazone; acetone hydrazone; acetone
25 phenylhydrazone; pinacolone hydrazone; pinacolone phenylhydrazone; benzaldehyde hydrazone;
benzaldehyde phenylhydrazone; naphthaldehyde hydrazone; naphthaldehyde phenylhydrazone;
norbornanone hydrazone; norbornanone phenylhydrazone; camphor hydrazone; camphor
phenylhydrazone; nopinone hydrazone; nopinone phenylhydrazone; 2-pyridinaldehyde
hydrazone; 2-pyridinealdehyde phenylhydrazone; salicylaldehyde hydrazone; salicylaldehyde
30 phenylhydrazone; quinolinaldehyde hydrazone; quinolinaldehyde phenylhydrazone; isatin

dihydrazone; isatin di(phenylhydrazone); camphorquinone dihydrazone; camphorquinone di(phenylhydrazone); and 2-hydrazinobenzimidazole hydrazone.

N Valence Stabilizer #13: Examples of azo compounds without chelate substitution at the ortho-
5 (for aryl) or alpha- or beta- (for alkyl) positions, bis(azo compounds), or poly(azo compounds) (N Monodentates, N-N Bidentates, or N-N Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: azobenzene (diphenyldiazene); p-diaminoazobenzene; p-dimethylaminoazobenzene (butter yellow); methyl orange; Fast Garnet GBC (4'-amino-2,3'-dimethylazobenzene)[Note: non-bonding methyl group
10 in the o-position.]; and Alizarin Yellow R. [Note: azo compounds without chelate substitution at the ortho- (for aryl) or beta- (for alkyl) positions tend to stabilize lower oxidation states in metal ions.]

N Valence Stabilizer #14: Examples of formazans, bis(formazans), and poly(formazans) without
15 ortho- hydroxy, carboxy, thiol, mercapto, amino, or hydrazido substitution (N-N Bidentates, N-N Tetridentates, and N-N Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,3,5-triphenylformazan; and 1,3,5-naphthylformazan.

20 N Valence Stabilizer #15: Examples of hydramides (N-N Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hydrobenzamide; hydronaphthamide; and hydrosalicylamide.

N Valence Stabilizer #16: Examples of azines (including ketazines), bis(azines), and
25 poly(azines) without ortho- hydroxy, carboxy, thiol, mercapto, amino, or hydrazido substitution (N-N Bidentates, N-N Tetridentates, and N-N Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: benzalazine; naphthalazine; cyclohexanonazine; and norbornonazine.

30 N Valence Stabilizer #17: Examples of Schiff Bases with one Imine (C=N) Group and without ortho- (for aryl constituents) or alpha- or beta- (for alkyl constituents) hydroxy, carboxy,

carbonyl, thiol, mercapto, thiocarbonyl, amino, imino, oximo, diazeno, or hydrazido substitution (N Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N-(Benzaldehydo)isopropylamine; N-

(Naphthaldehydo)isopropylamine; N-(Acetophenono)isopropylamine; N-

- 5 (Propiophenono)isopropylamine; N-(Benzaldehydo)cyclohexylamine; N-(Naphthaldehydo)cyclohexylamine; N-(Acetophenono)cyclohexylamine; N-(Propiophenono)cyclohexylamine; N-(Benzaldehydo)aniline (BAAN); N-(Naphthaldehydo)aniline; N-(Acetophenono)aniline; N-(Propiophenono)aniline; N-(Benzaldehydo)aminonorbornane; N-(Naphthaldehydo)aminonorbornane; N-

- 10 (Acetophenono)aminonorbornane; N-(Propiophenono)aminonorbornane; (Vanillino)anisidine; (Cinnamaldehydo)anisidine; N-(o-carboxycinnamaldehydo)aniline; N-(cinnamaldehydo)aniline; N-(cinnamaldehydo)m- or p-anisidine; and N-(o-carboxycinnamaldehydo)m- or p-anisidine.

N Valence Stabilizer #18: Examples of isocyanide and cyanamide and related ligands (N

- 15 Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: isocyanate (-NCO); isothiocyanate (-NCS); isoselenocyanate (-NCS_{Se}); and cyanamide (-NCN). [Note: the nitrogen atom is directly complexed to the high valence metal ion.]

- 20 N Valence Stabilizer #19: Examples of nitrosyls and nitrites and related ligands (N

Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: nitrosyl (-NO); thionitrosyl (-NS); nitrite (-NO₂); thionitrite (sulfinylamide)(thiazate)(-NSO); nitrosamine (=NN=O); thionitrosamine (=NN=S); nitramine (=NNO₂); and thionitramine (=NNS₂) ligands.

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N Valence Stabilizer #20: Examples of nitriles, dinitriles, and polynitriles (N Monodentates, N-N Bidentates, N-N Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: benzonitrile; naphthonitrile; cyanonaphthalene; cyclohexyl nitrile; cyanopyridine; cyanopurine; cyanophenol; cyanothiophenol; adamantane nitrile; norbornyl nitrile; cinnamonitrile; dicyanobenzene; dicyanobutene; dicyanoimidazole; dicyanopyridine; cyanotolunitrile; tetracyanoethylene

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(TCNE); tetracyanoquinodimethane (TCNQ); diethylaminopropionitrile (deapn), and polyacrylonitriles.

N Valence Stabilizer #21: Examples of azide ligands (N monodentates) that meet the

- 5 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: azide ($-\text{N}_3$) ions; methyl azide; ethyl azide; phenyl azide; diphenyltriazene; and phenyl sulfonyl azide.

S Valence Stabilizer #1: Examples of monothioethers (S monodentates) that meet the

- 10 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hydrogen sulfide, dimethyl sulfide, diethyl sulfide, dioctyl sulfide, diphenyl sulfide, dicyclohexyl sulfide, tetramethylene sulfide (tetrahydrothiophene, tht), trimethylene sulfide, dimethylene sulfide (ethylene sulfide), pentamethylene sulfide, 1,4-thioxane, oxathiolane, cyclohexene sulfide, cyclooctene sulfide, benzotetrahydrothiophene, dibenzothiophene,
15 naphthotetrahydrothiophene, and thiabicycloheptane.

S Valence Stabilizer #2: Examples of disulfides (S monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl disulfide, ethyl disulfide, phenyl disulfide, nitrophenide, and 1,2-dithiacyclohexane.

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S Valence Stabilizer #3: Examples of dithioethers (S monodentates or S-S bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,3-dithiane, 1,4-dithiane, benzodithiane, dibenzodithiane, naphthodithiane, 2,5-dithiahexane (dth); 3,6-dithiaoctane (dto); 2,5-dimethyl-3,6-dithiaoctane; 3,7-dithianonane; 2,6-dithiaheptane; 1,6-diphenyl-2,5-dithiahexane; 1,4-diphenyl-1,4-dithiabutane; 1,3-dithiolane; 1,4-dithiane (1,4-dithiacyclohexane); 1,4-dithiacycloheptane (dtch); 1,5-dithiacyclooctane (dtco); o-phenylenebis(2-thiapropane); o-phenylenebis(2-thiabutane); 2,2'-(thiamethyl)biphenyl, and 2,2'-(thiaethyl)biphenyl.

- 30 S Valence Stabilizer #4: Examples of trithioethers (S monodentates, S-S bidentates, or S-S tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4}

include, but are not limited to: 1,3,5-trithiane; 1,3,5-tris(methylthia)cyclohexane; 1,3,5-tris(ethylthia)cyclohexane; 1,3,5-tris(phenylthia)cyclohexane; 2,5,8-trithianonane; 3,6,9-trithiaundecane; and 2,6,10-trithiaundecane.

- 5 S Valence Stabilizer #5: Examples of tetrathioethers (S monodentates, S-S bidentates, S-S tridentates, or S-S tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,4,10,13-tetrathiatridecane; 2,6,10,14-tetrathiapentadecane; 2,5,8,11-tetrathiadodecane; 2,5,9,12-tetrathiatridecane; 2,6,9,13-tetrathiatetradecane; 1,4-(o-thiomethyl)phenyl-1,4-dithiabutane; 1,5-(o-thiomethyl)phenyl-1,5-dithiapentane; 1,6-(o-thiomethyl)phenyl-1,6-dithiahexane; 1,4-(o-thiomethyl)phenyl-1,4-dithiabut-2-ene; and polythioethers.
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- S Valence Stabilizer #6: Examples of hexathioethers (S monodentates, S-S bidentates, S-S tridentates, S-S tetradentates, or S-S hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-((o-thiomethyl)phenyl)ethyl)amine; and tri((o-thiomethyl)phenyl)methylamine.
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- S Valence Stabilizer #7a: Examples of 5-membered heterocyclic rings containing one sulfur atom (S monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydrothiophene, thiophene, thiazole, thiapyrroline, thiaphospholene, thiaphosphole, oxathiole, thiadiazole, thiaziazole, benzodihydrothiophene, benzothiophene, benzothiazole, benzothiaphosphole, dibenzothiophene, and naphthothiophene.
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- S Valence Stabilizer #7b: Examples of 5-membered heterocyclic rings containing two sulfur atoms (S monodentates or S-S bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiole, benzodithiole, and naphthodithiole.
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- S Valence Stabilizer #8a: Examples of 6-membered heterocyclic rings containing one sulfur atom (S monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydrothiopyran, thiopyran, thiazine, thiadiazine,
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thiaphosphorin, thiadiphosphorin, oxathiin, benzothiopyran, dibenzothiopyran, and naphthothiopyran.

S Valence Stabilizer #8b: Examples of 6-membered heterocyclic rings containing two sulfur

- 5 atoms (S monodentates or S-S bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydrodithiin, dithiin, benzodithiin, dibenzodithiin (thianthrene), and naphthodithiin.

S Valence Stabilizer #9a: Examples of 5-membered heterocyclic rings containing one sulfur

- 10 atom and having at least one additional sulfur atom binding site not contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,5-dimercapto-2,5-dihydrothiophene; 2,5-bis(thiomethyl)-2,5-dihydrothiophene; 2,5-bis(2-thiophenyl)-2,5-dihydrothiophene; 2,5-dimercaptothiophene; 2,5-bis(thiomethyl)thiophene;
- 15 2,5-bis(2-thiophenyl)thiophene; 2,5-dimercatothiazole; 2,5-bis(thiomethyl)thiazole; 2,5-bis(2-thiophenyl)thiazole; 2,5-dimercapto-1,3,4-thiadiazole [bismuththiol]; 2-mercaptothianaphthene; 7-(thiomethyl)thianaphthene; 1,8-dimercaptodibenzothiophene; 2-mercaptobenzothiazole; 2-mercapto-1,3,4-thiadiazole; 2-amino-5-mercapto-1,3,4-thiadiazole; 2,5-bis(alkylthio)-1,3,4-thiadiazole; and 7-(thiomethyl)benzothiazole.

20

S Valence Stabilizer #9b: Examples of 5-membered heterocyclic rings containing two sulfur

- atoms and having at least one additional sulfur atom binding site not contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not
- 25 limited to: 2-mercapto-1,3-dithiole; 2-(dimercaptomethyl)-1,3-dithiole; 4,5-dimercapto-1,3-dithiole; 4,5-bis(2-thiophenyl)-1,3-dithiole; 2-mercaptobenzodithiole; and 7-mercaptobenzodithiole.

S Valence Stabilizer #10a: Examples of 6-membered heterocyclic rings containing one sulfur

- 30 atom and having at least one additional sulfur atom binding site not contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that

meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,6-dimercapto-2,5-dihydrothiopyran; 2,6-bis(thiomethyl)-2,5-dihydrothiopyran; 2,6-bis(2-thiophenyl)-2,5-dihydrothiopyran; 2,6-dimercaptothiopyran; 2,6-bis(thiomethyl)thiopyran; 2,6-bis(2-thiophenyl)thiopyran; 2,6-dimercaptothiazine; 2,6-bis(thiomethyl)thiazine; 2,6-bis(2-thiophenyl)thiazine; 2,6-dimercapto-1,3,5-thiadiazine; 2-mercapto-1-benzothiopyran; 8-mercapto-1-benzothiopyran; and 1,9-dimercaptodibenzothiopyran.

S Valence Stabilizer #10b: Examples of 6-membered heterocyclic rings containing two sulfur atoms and having at least one additional sulfur atom binding site not contained in a ring (S

Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercapto-1,4-dithiin; 2,6-dimercapto-1,4-dithiin; 2,6-bis(2-thiophenyl)-1,4-dithiin; 2,3-dimercapto-1,4-benzodithiin; 5,8-dimercapto-1,4-benzodithiin; 1,8-dimercaptothianthrene; and 1,4,5,8-tetramercaptothianthrene.

S Valence Stabilizer #11a: Examples of 5-membered heterocyclic rings containing one sulfur atom and having at least one additional sulfur atom binding site contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2,5-dihydrothiophene; 2,2',2''-tri-2,5-dihydrothiophene; 2,2'-bithiophene; 2,2',2''-trithiophene; 2,2'-bithiazole; 5,5'-bithiazole; 2,2'-bioxathiole; 2,2'-bi-1,3,4-thiadiazole; 2,2'-bithianaphthene; 2,2'-bibenzothiazole; 1,1'-bis(dibenzothiophene); and polythiophenes.

S Valence Stabilizer #11b: Examples of 5-membered heterocyclic rings containing two sulfur

atoms and having at least one additional sulfur atom binding site contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-1,3-dithiole; 4,4'-bi-1,3-dithiole; 7,7'-bi-1,2-benzodithiole; 3,3'-bi-1,2-benzodithiole; and tetrathiofulvalene.

S Valence Stabilizer #12a: Examples of 6-membered heterocyclic rings containing one sulfur atom and having at least one additional sulfur atom binding site contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2,5-dihydrothiopyran; 2,2',2''-tri-2,5-dihydrothiopyran; 2,2'-bithiopyran; 2,2',2''-trithiopyran; 2,2'-bi-1,4-thiazine; 2,2'-bi-1,3,5-thiadiazine; 2,2'-bi-1-benzothiopyran; and 1,1'-bis(dibenzothiopyran)

S Valence Stabilizer #12b: Examples of 6-membered heterocyclic rings containing two sulfur atoms and having at least one additional sulfur atom binding site contained in a ring (S Monodentates, S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-1,4-dithiin; 2,2'-bi-1,3-dithiin; 5,5'-bi-1,4-benzodithiin; 2,2'-bi-1,3-benzodithiin; and 1,1'-bithianthrene.

S Valence Stabilizer #13a: Examples of two-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein both binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in component heterocyclic rings (S-S Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiacyclobutane ([4]aneS₂); dithiacyclopentane ([5]aneS₂); dithiacyclohexane ([6]aneS₂); dithiacycloheptane ([7]aneS₂); dithiacyclooctane ([8]aneS₂); dithiacyclobutene ([4]eneS₂); dithiacyclopentene ([5]eneS₂); dithiacyclohexene ([6]eneS₂); dithiacycloheptene ([7]eneS₂); dithiacyclooctene ([8]eneS₂); dithiacyclobutadiene ([4]dieneS₂); dithiacyclopentadiene ([5]dieneS₂); dithiacyclohexadiene ([6]dieneS₂); dithiacycloheptadiene ([7]dieneS₂); and dithiacyclooctadiene ([8]dieneS₂).

S Valence Stabilizer #13b: Examples of three-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in component heterocyclic rings (S-S Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trithiacyclohexane ([6]aneS₃);

- trithiacycloheptane ([7]aneS₃); trithiacyclooctane ([8]aneS₃); trithiacyclononane ([9]aneS₃);
trithiacyclodecane ([10]aneS₃); trithiacycloundecane ([11]aneS₃); trithiacyclododecane
([12]aneS₃); trithiacyclohexene ([6]eneS₃); trithiacycloheptene ([7]eneS₃); trithiacyclooctene
([8]eneS₃); trithiacyclononene ([9]eneS₃); trithiacyclodecene ([10]eneS₃); trithiacycloundecene
5 ([11]eneS₃); trithiacyclododecene ([12]eneS₃); trithiacyclohexatriene ([6]trieneS₃);
trithiacycloheptatriene ([7]trieneS₃); trithiacyclooctatriene ([8]trieneS₃); trithiacyclononatriene
([9]trieneS₃); trithiacyclodecatriene ([10]trieneS₃); trithiacycloundecatriene ([11]trieneS₃); and
trithiacyclododecatriene ([12]trieneS₃).
- 10 S Valence Stabilizer #13c: Examples of four-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in
component heterocyclic rings (S-S Tetradentates) that meet the requirements for use as “narrow
band” valence stabilizers for Ce⁺⁴ include, but are not limited to: tetrathiacyclooctane ([8]aneS₄);
15 tetrathiacyclononane ([9]aneS₄); tetrathiacyclodecane ([10]aneS₄); tetrathiacycloundecane
([11]aneS₄); tetrathiacyclododecane ([12]aneS₄); tetrathiacyclotridecane ([13]aneS₄);
tetrathiacyclotetradecane ([14]aneS₄); tetrathiacyclopentadecane ([15]aneS₄);
tetrathiacyclohexadecane ([16]aneS₄); tetrathiacycloheptadecane ([17]aneS₄);
tetrathiacyclooctadecane ([18]aneS₄); tetrathiacyclononadecane ([19]aneS₄);
20 tetrathiacycloeicosane ([20]aneS₄); tetrathiacyclooctadiene ([8]dieneS₄); tetrathiacyclononadiene
([9]dieneS₄); tetrathiacyclodecadiene ([10]dieneS₄); tetrathiacycloundecadiene ([11]dieneS₄);
tetrathiacyclododecadiene ([12]dieneS₄); tetrathiacyclotridecadiene ([13]dieneS₄);
tetrathiacyclotetradecadiene ([14]dieneS₄); tetrathiacyclopentadecadiene ([15]dieneS₄);
tetrathiacyclohexadecadiene ([16]dieneS₄); tetrathiacycloheptadecadiene ([17]dieneS₄);
25 tetrathiacyclooctadecadiene ([18]dieneS₄); tetrathiacyclononadecadiene ([19]dieneS₄);
tetrathiacycloeicosadiene ([20]dieneS₄); tetrathiacyclooctatetradiene ([8]tetradieneS₄);
tetrathiacyclononatetradiene ([9]tetradieneS₄); tetrathiacyclodecatetradiene ([10]tetradieneS₄);
tetrathiacycloundecatetradiene ([11]tetradieneS₄); tetrathiacyclododecatetradiene
([12]tetradieneS₄); tetrathiacyclotridecatetradiene ([13]tetradieneS₄);
30 tetrathiacyclotetradecatetradiene ([14]tetradieneS₄); tetrathiacyclopentadecatetradiene
([15]tetradieneS₄); tetrathiacyclohexadecatetradiene ([16]tetradieneS₄);

tetrathiacycloheptadecatetradene ([17]tetradeneS₄); tetrathiacyclooctadecatetradene ([18]tetradeneS₄); tetrathiacyclononadecatetradene ([19]tetradeneS₄); and tetrathiacycloeicosatetradene ([20]tetradeneS₄).

- 5 S Valence Stabilizer #13d: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in component heterocyclic rings (S-S Tridentates or S-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
- 10 pentathiacyclodecane ([10]aneS₅); pentathiacycloundecane ([11]aneS₅); pentathiacyclododecane ([12]aneS₅); pentathiacyclotridecane ([13]aneS₅); pentathiacyclotetradecane ([14]aneS₅); pentathiacyclopentadecane ([15]aneS₅); pentathiacyclodecatriene ([10]trieneS₅); pentathiacycloundecatriene ([11]trieneS₅); pentathiacyclododecatriene ([12]trieneS₅); pentathiacyclotridecatriene ([13]trieneS₅); pentathiacyclotetradecatriene ([14]trieneS₅); and
- 15 pentathiacyclopentadecatriene ([15]trieneS₅).

- S Valence Stabilizer #13e: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in
- 20 component heterocyclic rings (S-S Tridentates, S-S Tetradentates, or S-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: hexathiacyclododecane ([12]aneS₆); hexathiacyclotridecane ([13]aneS₆); hexathiacyclotetradecane ([14]aneS₆); hexathiacyclopentadecane ([15]aneS₆); hexathiacyclohexadecane ([16]aneS₆); hexathiacycloheptadecane ([17]aneS₆);
- 25 hexathiacyclooctadecane ([18]aneS₆); hexathiacyclononadecane ([19]aneS₆); hexathiacycloeicosane ([20]aneS₆); hexathiacycloheneicosane ([21]aneS₆); hexathiacyclodocosane ([22]aneS₆); hexathiacyclotricosane ([23]aneS₆); hexathiacyclotetracosane ([24]aneS₆); hexathiacyclododecatriene ([12]trieneS₆); hexathiacyclotridecatriene ([13]trieneS₆); hexathiacyclotetradecatriene ([14]trieneS₆);
- 30 hexathiacyclopentadecatriene ([15]trieneS₆); hexathiacyclohexadecatriene ([16]trieneS₆); hexathiacycloheptadecatriene ([17]trieneS₆); hexathiacyclooctadecatriene ([18]trieneS₆);

hexathiacyclononadecatriene ([19]trieneS₆); hexathiacycloeicosatriene ([20]trieneS₆);
hexathiacycloheneicosatriene ([21]trieneS₆); hexathiacyclodocosatriene ([22]trieneS₆);
hexathiacyclotricosatriene ([23]trieneS₆); and hexathiacyclotetracosatriene ([24]trieneS₆).

- 5 S Valence Stabilizer #13f: Examples of seven-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in
component heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that
meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not
10 limited to: heptathiacyclotetradecane ([14]aneS₇); heptathiacyclopentadecane ([15]aneS₇);
heptathiacyclohexadecane ([16]aneS₇); heptathiacycloheptadecane ([17]aneS₇);
heptathiacyclooctadecane ([18]aneS₇); heptathiacyclononadecane ([19]aneS₇);
heptathiacycloeicosane ([20]aneS₇); heptathiacycloheneicosane ([21]aneS₇);
heptathiacyclotetradecatriene ([14]trieneS₇); heptathiacyclopentadecatriene ([15]trieneS₇);
15 heptathiacyclohexadecatriene ([16]trieneS₇); heptathiacycloheptadecatriene ([17]trieneS₇);
heptathiacyclooctadecatriene ([18]trieneS₇); heptathiacyclononadecatriene ([19]trieneS₇);
heptathiacycloeicosatriene ([20]trieneS₇); and heptathiacycloheneicosatriene ([21]trieneS₇).

- S Valence Stabilizer #13g: Examples of eight-membered macrocyclics, macrobicyclics, and
20 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in
component heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that
meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not
limited to: octathiacyclohexadecane ([16]aneS₈); octathiacycloheptadecane ([17]aneS₈);
25 octathiacyclooctadecane ([18]aneS₈); octathiacyclononadecane ([19]aneS₈);
octathiacycloeicosane ([20]aneS₈); octathiacycloheneicosane ([21]aneS₈); octathiacyclodocosane
([22]aneS₈); octathiacyclotricosane ([23]aneS₈); octathiacyclotetracosane ([24]aneS₈);
octathiacyclohexadecatetradene ([16]tetradeneS₈); octathiacycloheptadecatetradene
([17]tetradeneS₈); octathiacyclooctadecatetradene ([18]tetradeneS₈);
30 octathiacyclononadecatetradene ([19]tetradeneS₈); octathiacycloeicosatetradene
([20]tetradeneS₈); octathiacycloheneicosatetradene ([21]tetradeneS₈);

octathiacyclodocosatetradene ([22]tetradeneS₈); octathiacyclotricosatetradene ([23]tetradeneS₈); and octathiacyclotetracosatetradene ([24]tetradeneS₈).

S Valence Stabilizer #13h: Examples of nine-membered macrocyclics, macrobicyclics, and

- 5 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in component heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: nonathiacyclooctadecane ([18]aneS₉); nonathiacyclononadecane ([19]aneS₉);
- 10 nonathiacycloeicosane ([20]aneS₉); nonathiacycloheneicosane ([21]aneS₉); nonathiacyclodocosane ([22]aneS₉); nonathiacyclotricosane ([23]aneS₉); nonathiacyclotetracosane ([24]aneS₉); nonathiacyclopentacosane ([25]aneS₉); nonathiacyclohexacosane ([26]aneS₉); nonathiacycloheptacosane ([27]aneS₉); nonathiacyclooctadecatetradene ([18]tetradeneS₉); nonathiacyclononadecatetradene
- 15 ([19]tetradeneS₉); nonathiacycloeicosatetradene ([20]tetradeneS₉); nonathiacycloheneicosatetradene ([21]tetradeneS₉); nonathiacyclodocosatetradene ([22]tetradeneS₉); nonathiacyclotricosatetradene ([23]tetradeneS₉); nonathiacyclotetracosatetradene ([24]tetradeneS₉); nonathiacyclopentacosatetradene ([25]tetradeneS₉); nonathiacyclohexacosatetradene ([26]tetradeneS₉); and
- 20 nonathiacycloheptacosatetradene ([27]tetradeneS₉).

S Valence Stabilizer #13i: Examples of ten-membered macrocyclics, macrobicyclics, and

- macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol or thioether groups) and are not contained in
- 25 component heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: decathiacycloeicosane ([20]aneS₁₀); decathiacycloheneicosane ([21]aneS₁₀); decathiacyclodocosane ([22]aneS₁₀); decathiacyclotricosane ([23]aneS₁₀); decathiacyclotetracosane ([24]aneS₁₀); decathiacyclopentacosane ([25]aneS₁₀);
- 30 decathiacyclohexacosane ([26]aneS₁₀); decathiacycloheptacosane ([27]aneS₁₀); decathiacyclooctacosane ([28]aneS₁₀); decathiacyclononacosane ([29]aneS₁₀);

- decathiacyclotriacontane ([30]aneS₁₀); decathiacycloeicosapentadiene ([20]pentadieneS₁₀);
decathiacycloheneicosapentadiene ([21]pentadieneS₁₀); decathiacyclodocosapentadiene
([22]pentadieneS₁₀); decathiacyclotricosapentadiene ([23]pentadieneS₁₀);
decathiacyclotetracosapentadiene ([24]pentadieneS₁₀); decathiacyclopentacosapentadiene
5 ([25]pentadieneS₁₀); decathiacyclohexacosapentadiene ([26]pentadieneS₁₀);
decathiacycloheptacosapentadiene ([27]pentadieneS₁₀); decathiacyclooctacosapentadiene
([28]pentadieneS₁₀); decathiacyclononacosapentadiene ([29]pentadieneS₁₀); and
decathiacyclotriacontapentadiene ([30]pentadieneS₁₀).
- 10 S Valence Stabilizer #14a: Examples of four-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
four binding sites are composed of sulfur and are contained in component 5-membered
heterocyclic rings (S-S Tetradentates) that meet the requirements for use as “narrow band”
valence stabilizers for Ce⁺⁴ include, but are not limited to: tetrathiophenes; tetrathiazoles;
15 tetrathiaphospholes; tetraoxathioles; tetrathiadiazoles; tetrathiatriazoles; and tetradithioles.
- S Valence Stabilizer #14b: Examples of five-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
five binding sites are composed of sulfur and are contained in component 5-membered
20 heterocyclic rings (S-S Tridentates or S-S Tetradentates) that meet the requirements for use as
“narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: pentathiophenes;
pentathiazoles; pentathiaphospholes; pentaoxathioles; pentathiadiazoles; pentathiatriazoles; and
pentadithioles.
- 25 S Valence Stabilizer #14c: Examples of six-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
six binding sites are composed of sulfur and are contained in component 5-membered
heterocyclic rings (S-S Tridentates, S-S Tetradentates, or S-S Hexadentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
30 hexathiophenes; hexathiazoles; hexathiaphospholes; hexaoxathioles; hexathiadiazoles;
hexathiatriazoles; and hexadithioles.

S Valence Stabilizer #14d: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all seven binding sites are composed of sulfur and are contained in component 5-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: heptathiophenes; heptathiazoles; heptathiaphospholes; heptaoxathioles; heptathiadiazoles; heptathiatriazoles; and heptadithioles.

S Valence Stabilizer #14e: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of sulfur and are contained in component 5-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: octathiophenes; octathiazoles; octathiaphospholes; octaoxathioles; octathiadiazoles; octathiatriazoles; and octadithioles.

S Valence Stabilizer #14f: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all nine binding sites are composed of sulfur and are contained in component 5-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: nonathiophenes; nonathiazoles; nonathiaphospholes; nonaoxathioles; nonathiadiazoles; nonathiatriazoles; and nonadithioles.

S Valence Stabilizer #14g: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of sulfur and are contained in component 5-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: decathiophenes; decathiazoles; decathiaphospholes; decaoxathioles; decathiadiazoles; decathiatriazoles; and decadithioles.

S Valence Stabilizer #15a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiatetrathiophenes; tetrathiatetrathiophenes; dithiatetradithioles; and tetrathiatetradithioles.

S Valence Stabilizer #15b: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cydidenes, and sepulchrates) wherein all five binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates or S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiapentathiophenes; tetrathiapentathiophenes; dithiapentadithioles; and tetrathiapentadithioles.

S Valence Stabilizer #15c: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetridentates, or S-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiahexaathiophenes; trithiahexathiophenes; dithiahexadithioles; and trithiahexadithioles.

S Valence Stabilizer #15d: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all seven binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetridentates, or S-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiaheptathiophenes; tetrathiaheptathiophenes; dithiaheptadithioles; and tetrathiaheptadithioles.

S Valence Stabilizer #15e: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiaoctathiophenes; tetrathiaoctathiophenes; dithiaoctadithioles; and tetrathiaoctadithioles.

S Valence Stabilizer #15f: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all nine binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trithianonathiophenes; hexathianonathiophenes; trithianonadithioles; and hexathianonadithioles.

S Valence Stabilizer #15g: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of sulfur and are contained in a combination of 5-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiadecathiophenes; pentathiadecathiophenes; dithiadecadithioles; and pentathiadecadithioles.

S Valence Stabilizer #16a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrathiopyrans; tetrathiazines; tetrathiaphosphorins; tetrathiadiphosphorins; tetraoxathiins; and tetradithiins.

S Valence Stabilizer #16b: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all five binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates or S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: pentathiopyrans; pentathiazines; pentathiaphosphorins; pentathiadiphosphorins; pentaoxathiins; and pentadithiins.

S Valence Stabilizer #16c: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hexathiopyrans; hexathiazines; hexathiaphosphorins; hexathiadiphosphorins; hexaoxathiins; and hexadithiins.

S Valence Stabilizer #16d: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all seven binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: heptathiopyrans; heptathiazines; heptathiaphosphorins; heptathiadiphosphorins; heptaoxathiins; and heptadithiins.

S Valence Stabilizer #16e: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: octathiopyrans; octathiazines; octathiaphosphorins; octathiadiphosphorins; octaoxathiins; and octadithiins.

S Valence Stabilizer #16f: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all nine binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: nonathiopyrans; nonathiazines; nonathiaphosphorins; nonathiadiphosphorins; nonaoxathiins; and nonadithiins.

S Valence Stabilizer #16g: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of sulfur and are contained in component 6-membered heterocyclic rings (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: decathiopyrans; decathiazines; decathiaphosphorins; decathiadiphosphorins; decaoxathiins; and decadithiins.

S Valence Stabilizer #17a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of sulfur and are contained in a combination of 6-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiatetrathiopyrans; tetrathiatetrathiopyrans; dithiatetrathiazines; tetrathiatetrathiazines; dithiatetrathiaphosphorins; tetrathiatetrathiaphosphorins; dithiatetraoxathiins; tetrathiatetraoxathiins; dithiatetradithiins; and tetrathiatetradithiins.

S Valence Stabilizer #17b: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all five binding sites are composed of sulfur and are contained in a combination of 6-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates or S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiapentathiopyrans; tetrathiapentathiopyrans; dithiapentathiazines;

tetrathiapentathiazines; dithiapentathiaphosphorins; tetrathiapentathiaphosphorins;
dithiapentaoxathiins; tetrathiapentaoxathiins; dithiapentadithiins; and tetrathiapentadithiins.

S Valence Stabilizer #17c: Examples of six-membered macrocyclics, macrobicyclics, and

- 5 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
six binding sites are composed of sulfur and are contained in a combination of 6-membered
heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or
S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for
Ce⁺⁴ include, but are not limited to: dithiahexathiopyrans; trithiahexathiopyrans;
10 dithiahexathiazines; trithiahexathiazines; dithiahexathiaphosphorins; trithiahexathiaphosphorins;
dithiahexaoxathiins; trithiahexaoxathiins; dithiahexadithiins; and trithiahexadithiins.

S Valence Stabilizer #17d: Examples of seven-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

- 15 seven binding sites are composed of sulfur and are contained in a combination of 6-membered
heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or
S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for
Ce⁺⁴ include, but are not limited to: dithiaheptathiopyrans; tetrathiaheptathiopyrans;
dithiaheptathiazines; tetrathiaheptathiazines; dithiaheptathiaphosphorins;
20 tetrathiaheptathiaphosphorins; dithiaheptaoxathiins; tetrathiaheptaoxathiins; dithiaheptadithiins;
and tetrathiaheptadithiins.

S Valence Stabilizer #17e: Examples of eight-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

- 25 eight binding sites are composed of sulfur and are contained in a combination of 6-membered
heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or
S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for
Ce⁺⁴ include, but are not limited to: dithiaoctathiopyrans; tetrathiaoctathiopyrans;
dithiaoctathiazines; tetrathiaoctathiazines; dithiaoctathiaphosphorins;
30 tetrathiaoctathiaphosphorins; dithiaoctaoxathiins; tetrathiaoctaoxathiins; dithiaoctadithiins; and
tetrathiaoctadithiins.

S Valence Stabilizer #17f: Examples of nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all nine binding sites are composed of sulfur and are contained in a combination of 6-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trithianonathiopyrans; hexathianonathiopyrans; trithianonathiazines; hexathianonathiazines; trithianonathiaphosphorins; hexathianonathiaphosphorins; trithianonaoxathiins; hexathianonaoxathiins; trithianonadithiins; and hexathianonadithiins.

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S Valence Stabilizer #17g: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all ten binding sites are composed of sulfur and are contained in a combination of 6-membered heterocyclic rings and thiol, thioether, or thioketo groups (S-S Tridentates, S-S Tetracentates, or S-S Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiadecathiopyrans; pentathiadecathiopyrans; dithiadecathiazines; pentathiadecathiazines; dithiadecathiaphosphorins; pentathiadecathiaphosphorins; dithiadecaoxathiins; pentathiadecaoxathiins; dithiadecadithiins; and pentathiadecadithiins.

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S Valence Stabilizer #18: Examples of dithiobiurets (dithioimidodicarbonic diamides), dithioisobiurets, dithiobiureas, trithiotriurets, trithiotriureas, bis(dithiobiurets), bis(dithioisobiurets), bis(dithiobiureas), poly(dithiobiurets), poly(dithioisobiurets), and poly(dithiobiureas) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiobiuret, dithioisobiuret, dithiobiurea, trithiotriuret, trithiotriurea, nitrodithiobiuret, dinitrodithiobiuret, aminodithiobiuret, diaminodithiobiuret, oxydithiobiuret, dioxydithiobiuret, cyanodithiobiuret, methyl dithiobiuret, ethyl dithiobiuret, isopropyl dithiobiuret, phenyl dithiobiuret, benzyl dithiobiuret, cyclohexyl dithiobiuret, norbornyl dithiobiuret, adamantyl dithiobiuret, dimethyl dithiobiuret, diethyl dithiobiuret, diisopropyl dithiobiuret,

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diphenyldithiobiuret, dibenzylthiobiuret, dicyclohexyldithiobiuret, dinorbornyldithiobiuret, and diadamantyldithiobiuret.

S Valence Stabilizer #19: Examples of thioacylthioureas, thioaroylthioureas,

- 5 bis(thioacylthioureas), bis(thioaroylthioureas), poly(thioacylthioureas), and poly(thioaroylthioureas) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thioformylthiourea, thioacetylthiourea, thiobenzoylthiourea, thiocyclohexoylthiourea, pentafluorothiobenzoylthiourea, N-methylthioacetylthiourea, N-phenylthiobenzoylthiourea, and
- 10 N-cyclohexylthiocyclohexoylthiourea.

S Valence Stabilizer #20: Examples of dithioacyl disulfides, bis(dithioacyl disulfides), and poly(dithioacyl disulfides), (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 15 dithioacetyl disulfide; dithiopropionyl disulfide; dithiobenzoyl disulfide; and dithiopentafluorobenzoyl disulfide.

S Valence Stabilizer #21: Examples of tetrathioperoxydicarbonic diamides,

- bis(tetrathioperoxydicarbonic diamides), and poly(tetrathioperoxydicarbonic diamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrathioperoxydicarbonic diamide; N-phenyltetrathioperoxydicarbonic diamide; N-benzyltetrathioperoxydicarbonic diamide; N-cyclohexyltetrathioperoxydicarbonic diamide; N-norbornyltetrathioperoxydicarbonic diamide; N,N'-diphenyltetrathioperoxydicarbonic diamide; N,N'-
- 20 dibenzyltetrathioperoxydicarbonic diamide; N,N'-dicyclohexyltetrathioperoxydicarbonic diamide; and N,N'-dinorbornyltetrathioperoxydicarbonic diamide.

S Valence Stabilizer #22: Examples of hexathio-, pentathio-, and tetrathioperoxydicarbonic

- acids, bis(hexathio-, pentathio-, and tetrathioperoxydicarbonic acids), poly(hexathio-, pentathio-, and tetrathioperoxydicarbonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4}
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include, but are not limited to: hexathioperoxydicarbonic acid, pentathioperoxydicarbonic acid, tetrathioperoxydicarbonic acid, S-phenylhexathioperoxydicarbonic acid; S-benzylhexathioperoxydicarbonic acid; S-cyclohexylhexathioperoxydicarbonic acid; S-norbornylhexathioperoxydicarbonic acid; S,S'-diphenylhexathioperoxydicarbonic acid; S,S'-dibenzylhexathioperoxydicarbonic acid; S,S'-dicyclohexylhexathioperoxydicarbonic acid; and S,S'-dinorbornylhexathioperoxydicarbonic acid.

S Valence Stabilizer #23: Examples of dithioperoxydiphosphoramides, bis(dithioperoxydiphosphoramides), and poly(dithioperoxydiphosphoramides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioperoxydiphosphoramide, N-methyldithioperoxydiphosphoramide, N-isopropyldithioperoxydiphosphoramide, N-tert-butyl dithioperoxydiphosphoramide, N-phenyldithioperoxydiphosphoramide, N-pentafluorophenyldithioperoxydiphosphoramide, N-benzyl dithioperoxydiphosphoramide, N-cyclohexyldithioperoxydiphosphoramide, N-norbornyldithioperoxydiphosphoramide, N,N''-dimethyldithioperoxydiphosphoramide, N,N''-diisopropyldithioperoxydiphosphoramide, N,N''-di-tert-butyl dithioperoxydiphosphoramide, N,N''-diphenyldithioperoxydiphosphoramide, N,N''-di-pentafluorophenyldithioperoxydiphosphoramide, N,N''-dibenzyl dithioperoxydiphosphoramide, N,N''-dicyclohexyldithioperoxydiphosphoramide, and N,N''-dinorbornyldithioperoxydiphosphoramide.

S Valence Stabilizer #24: Examples of dithioperoxydiphosphoric acids, bis(dithioperoxydiphosphoric acids), poly(dithioperoxydiphosphoric acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioperoxydiphosphoric acid, methyldithioperoxydiphosphoric acid, isopropyldithioperoxydiphosphoric acid, tert-butyl dithioperoxydiphosphoric acid, phenyldithioperoxydiphosphoric acid, pentafluorophenyldithioperoxydiphosphoric acid, benzyl dithioperoxydiphosphoric acid, cyclohexyldithioperoxydiphosphoric acid, norbornyldithioperoxydiphosphoric acid, dimethyldithioperoxydiphosphoric acid, diisopropyldithioperoxydiphosphoric acid, di-tert-butyl dithioperoxydiphosphoric acid,

diphenyldithioperoxydiphosphoric acid, di-pentafluorophenyldithioperoxydiphosphoric acid, dibenzylthioperoxydiphosphoric acid, dicyclohexyldithioperoxydiphosphoric acid, and dinorbornyldithioperoxydiphosphoric acid.

- 5 S Valence Stabilizer #25: Examples of dithioimidodiphosphonic acids, dithiohydrazidodiphosphonic acids, bis(dithioimidodiphosphonic acids), bis(dithiohydrazidodiphosphonic acids), poly(dithioimidodiphosphonic acids), poly(dithiohydrazidodiphosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence
- 10 stabilizers for Ce^{+4} include, but are not limited to: dithioimidodiphosphonic acid, methyldithioimidodiphosphonic acid, isopropyldithioimidodiphosphonic acid, tert-butylthioimidodiphosphonic acid, phenyldithioimidodiphosphonic acid, pentafluorophenyldithioimidodiphosphonic acid, benzyldithioimidodiphosphonic acid, cyclohexyldithioimidodiphosphonic acid, norbornyldithioimidodiphosphonic acid,
- 15 dimethyldithioimidodiphosphonic acid, diisopropyldithioimidodiphosphonic acid, di-tert-butylthioimidodiphosphonic acid, diphenyldithioimidodiphosphonic acid, di-pentafluorophenyldithioimidodiphosphonic acid, dibenzylthioimidodiphosphonic acid, dicyclohexyldithioimidodiphosphonic acid, and dinorbornyldithioimidodiphosphonic acid.
- [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizaton of high valence
- 20 metal ions much more difficult, though still possible.]

- S Valence Stabilizer #26: Examples of dithioimidodiphosphonamides, dithiohydrazidodiphosphonamides, bis(dithioimidodiphosphonamides), bis(dithiohydrazidodiphosphonamides), poly(dithioimidodiphosphonamides), and
- 25 poly(dithiohydrazidodiphosphonamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioimidodiphosphonamide, N-methyldithioimidodiphosphonamide, N-isopropyldithioimidodiphosphonamide, N-tert-butylthioimidodiphosphonamide, N-phenyldithioimidodiphosphonamide, N-pentafluorophenyldithioimidodiphosphonamide, N-
- 30 benzyldithioimidodiphosphonamide, N-cyclohexyldithioimidodiphosphonamide, N-norbornyldithioimidodiphosphonamide, N,N”-dimethyldithioimidodiphosphonamide, N,N”-

diisopropyldithioimidodiphosphonamide, N,N'''-di-tert-butylthioimidodiphosphonamide, N,N'''-diphenyldithioimidodiphosphonamide, N,N'''-di-pentafluorophenyldithioimidodiphosphonamide, N,N'''-dibenzylthioimidodiphosphonamide, N,N'''-dicyclohexyldithioimidodiphosphonamide, and N,N'''-

- 5 dinorbornyldithioimidodiphosphonamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S Valence Stabilizer #27: Examples of dithiodiphosphonamides, bis(dithiodiphosphonamides), and poly(dithiodiphosphonamides) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that

- 10 meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodiphosphonamide, N-methyldithiodiphosphonamide, N-isopropyldithiodiphosphonamide, N-tert-butylthiodiphosphonamide, N-phenyldithiodiphosphonamide, N-pentafluorophenyldithiodiphosphonamide, N-benzylthiodiphosphonamide, N-cyclohexyldithiodiphosphonamide, N-
- 15 norbornyldithiodiphosphonamide, N,N'''-dimethyldithiodiphosphonamide, N,N'''-diisopropyldithiodiphosphonamide, N,N'''-di-tert-butylthiodiphosphonamide, N,N'''-diphenyldithiodiphosphonamide, N,N'''-di-pentafluorophenyldithiodiphosphonamide, N,N'''-dibenzylthiodiphosphonamide, N,N'''-dicyclohexyldithiodiphosphonamide, and N,N'''-dinorbornyldithiodiphosphonamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom
- 20 makes stabilizization of high valence metal ions much more difficult, though still possible.]

S Valence Stabilizer #28: Examples of dithiodiphosphonic acids, bis(dithiodiphosphonic acids), poly(dithiodiphosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4}

- 25 include, but are not limited to: dithiodiphosphonic acid, methyldithiodiphosphonic acid, isopropyldithiodiphosphonic acid, tert-butylthiodiphosphonic acid, phenyldithiodiphosphonic acid, pentafluorophenyldithiodiphosphonic acid, benzylthiodiphosphonic acid, cyclohexyldithiodiphosphonic acid, norbornyldithiodiphosphonic acid, dimethyldithiodiphosphonic acid, diisopropyldithiodiphosphonic acid, di-tert-
- 30 butylthiodiphosphonic acid, diphenyldithiodiphosphonic acid, di-pentafluorophenyldithiodiphosphonic acid, dibenzylthiodiphosphonic acid,

dicyclohexyldithiodiphosphonic acid, and dinorbornyldithiodiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

- 5 S Valence Stabilizer #29: Examples of dithioperoxydiphosponamides, bis(dithioperoxydiphosponamides), and poly(dithioperoxydiphosponamides) (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioperoxydiphosponamide, N-methyldithioperoxydiphosponamide, N-isopropyldithioperoxydiphosponamide, N-tert-butyl
- 10 dithioperoxydiphosponamide, N-phenyldithioperoxydiphosponamide, N-pentafluorophenyldithioperoxydiphosponamide, N-benzoyldithioperoxydiphosponamide, N-cyclohexyldithioperoxydiphosponamide, N-norbornyldithioperoxydiphosponamide, N,N”-dimethyldithioperoxydiphosponamide, N,N”-diisopropyldithioperoxydiphosponamide, N,N”-di-tert-butyl
- 15 dithioperoxydiphosponamide, N,N”-di-pentafluorophenyldithioperoxydiphosponamide, N,N”-dibenzoyldithioperoxydiphosponamide, N,N”-dicyclohexyldithioperoxydiphosponamide, and N,N”-dinorbornyldithioperoxydiphosponamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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- S Valence Stabilizer #30: Examples of dithioperoxydiphosphonic acids, bis(dithioperoxydiphosphonic acids), poly(dithioperoxydiphosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 25 dithioperoxydiphosphonic acid, methyldithioperoxydiphosphonic acid, isopropyldithioperoxydiphosphonic acid, tert-butyl
- phenyldithioperoxydiphosphonic acid, pentafluorophenyldithioperoxydiphosphonic acid, benzoyldithioperoxydiphosphonic acid, cyclohexyldithioperoxydiphosphonic acid, norbornyldithioperoxydiphosphonic acid, dimethyldithioperoxydiphosphonic acid,
- 30 diisopropyldithioperoxydiphosphonic acid, di-tert-butyl
- dithioperoxydiphosphonic acid, di-pentafluorophenyldithioperoxydiphosphonic acid,

dibenzylthioperoxydiphosphonic acid, dicyclohexylthioperoxydiphosphonic acid, and dinorbornylthioperoxydiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

5 S Valence Stabilizer #31: Examples of dithiophosphonic acids (phosphonodithioic acids), bis(dithiophosphonic acids), poly(dithiophosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiophosphonic acid, O-phenylthiophosphonic acid, O-benzylthiophosphonic acid, O-cyclohexylthiophosphonic
10 acid, O-norbornylthiophosphonic acid, O,P-diphenylthiophosphonic acid, O,P-dibenzylthiophosphonic acid, O,P-dicyclohexylthiophosphonic acid, and O,P-dinorbornylthiophosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

15 S Valence Stabilizer #32: Examples of trithiophosphonic acids (phosphonotrithioic acids), bis(trithiophosphonic acids), poly(trithiophosphonic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trithiophosphonic acid, S-phenyltrithiophosphonic acid, S-benzyltrithiophosphonic acid, S-cyclohexyltrithiophosphonic
20 acid, S-norbornyltrithiophosphonic acid, S,P-diphenyltrithiophosphonic acid, S,P-dibenzyltrithiophosphonic acid, S,P-dicyclohexyltrithiophosphonic acid, and S,P-dinorbornyltrithiophosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

25 S Valence Stabilizer #33: Examples of phosphono(dithioperoxo)thioic acids, bis[phosphono(dithioperoxo)thioic acids], poly[phosphono(dithioperoxo)thioic acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphono(dithioperoxo)thioic acid, O-phenylphosphono(dithioperoxo)thioic acid, O-
30 benzylphosphono(dithioperoxo)thioic acid, O-cyclohexylphosphono(dithioperoxo)thioic acid, O-norbornylphosphono(dithioperoxo)thioic acid, O,P-diphenylphosphono(dithioperoxo)thioic acid,

O,P-dibenzylphosphono(dithioperoxo)thioic acid, O,P-dicyclohexylphosphono(dithioperoxo)thioic acid, and O,P-dinorbornylphosphono(dithioperoxo)thioic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though
5 still possible.]

S Valence Stabilizer #34: Examples of phosphono(dithioperoxo)dithioic acids, bis[phosphono(dithioperoxo)dithioic acids], poly[phosphono(dithioperoxo)dithioic acids], and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetracentates) that meet the
10 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphono(dithioperoxo)dithioic acid, S-phenylphosphono(dithioperoxo)dithioic acid, S-benzylphosphono(dithioperoxo)dithioic acid, S-cyclohexylphosphono(dithioperoxo)dithioic acid, S-norbornylphosphono(dithioperoxo)dithioic acid, S,P-diphenylphosphono(dithioperoxo)dithioic acid, S,P-dibenzylphosphono(dithioperoxo)dithioic acid, S,P-dicyclohexylphosphono(dithioperoxo)dithioic acid, and S,P-dinorbornylphosphono(dithioperoxo)dithioic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though
15 still possible.]

20 S Valence Stabilizer #35: Examples of S-(alkylthio)thiocarboxylic acids, S-(arylthio)thiocarboxylic acids, and S,S-thiobisthiocarboxylic Acids (S-S Bidentates and S-S Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: (methylthio)thioacetic acid; (methylthio)thiobenzoic acid; (methylthio)thionicotinic acid; (methylthio)thionaphthoic acid; (phenylthio)thioacetic acid; (phenylthio)thiobenzoic acid; (phenylthio)thionaphthoic acid; (norbornylthio)thioacetic acid; (norbornylthio)thiobenzoic acid; (norbornylthio)thionaphthoic acid; thiobisthiacetic acid; thiobisthiobenzoic acid; and thiobisthionaphthoic acid.
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S Valence Stabilizer #36: Examples of S-(alkyldisulfido)thiocarboxylic acids, S-(aryldisulfido)thiocarboxylic acids, and S,S'-disulfidobisthiocarboxylic acids (S-S Bidentates and S-S Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for
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Ce⁺⁴ include, but are not limited to: (methylsulphido)thioacetic acid; (methylsulphido)thiobenzoic acid; (methylsulphido)thionicotinic acid; (methylsulphido)thionaphthoic acid; (phenylsulphido)thioacetic acid; (phenylsulphido)thiobenzoic acid; (phenylsulphido)thionaphthoic acid; 5 (norbornylsulphido)thioacetic acid; (norbornylsulphido)thiobenzoic acid; (norbornylsulphido)thionaphthoic acid; S,S'-disulphidobisthioacetic acid; S,S'-disulphidobisthiobenzoic acid; and S,S'-disulphidobisthionaphthoic acid.

S Valence Stabilizer #37: Examples of 1,2-dithiolates, bis(1,2-dithiolates), and poly(1,2-

10 dithiolates) (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as "narrow band" valence stabilizers for Ce⁺⁴ include, but are not limited to: 2,3-butanedithiol; 1,2-diphenyl-1,2-ethanedithiol; 1,2-di(pentafluorophenyl)-1,2-ethanedithiol; 1,2-dicyclohexyl-1,2-ethanedithiol; 1,2-dinorbornyl-1,2-ethanedithiol; 2,3-dimercaptopropanol; 2,3-dimercaptosuccinic acid; poly[bis(arylthio)acetylene]s; and poly[bis(alkylthio)acetylene]s.

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S Valence Stabilizer #38: Examples of rhodanines and bis(rhodanines) (S-S Bidentates and S-S Tetridentates) that meet the requirements for use as "narrow band" valence stabilizers for Ce⁺⁴ include, but are not limited to: 3-methylrhodanine; 3-ethylrhodanine; 3-isopropylrhodanine; 3-phenylrhodanine; 3-benzylrhodanine; 3-cyclohexylrhodanine; 3-norbornylrhodanine; 5- 20 methylrhodanine; 5-ethylrhodanine; 5-isopropylrhodanine; 5-phenylrhodanine; 5-benzylrhodanine; 5-cyclohexylrhodanine; 5-norbornylrhodanine; 3,3'-ethylenebisrhodanine; 3,3'-propylenebisrhodanine; 3,3'-butylenebisrhodanine; 5,5'-ethylenebisrhodanine; 5,5'-propylenebisrhodanine; and 5,5'-butylenebisrhodanine. [Note: rhodanines and bis(rhodanines) tend to stabilize lower oxidation states in metal ions.]

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S Valence Stabilizer #39: Examples of dithiocarbimides, bis(dithiocarbimides), and poly(dithiocarbimides) (S-S Bidentates, S-S Tridentates, and S-S Tetridentates) that meet the requirements for use as "narrow band" valence stabilizers for Ce⁺⁴ include, but are not limited to: methylthiocarbimide; trifluoromethylthiocarbimide; ethylthiocarbimide; 30 propylthiocarbimide; isopropylthiocarbimide; butylthiocarbimide; tertbutylthiocarbimide; cyanodithiocarbimide (CDC); cyanamidodithiocarbimide; azidodithiocarbimide;

phenyldithiocarbamate; pentafluorophenyldithiocarbamate; benzyldithiocarbamate; naphthyldithiocarbamate; cyclohexyldithiocarbamate; norbornyldithiocarbamate; and adamantyldithiocarbamate. [Note: carbimates tend to stabilize lower oxidation states in metal ions.]

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S Valence Stabilizer #40: Examples of thioxanthates, bis(thioxanthates), and poly(thioxanthates) (S-S Bidentates and S-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl thioxanthate (MeSxan); ethyl thioxanthate (EtSxan); isopropyl thioxanthate (iPrSxan); trifluoromethyl thioxanthate (CF_3 Sxan); cyanothioxanthate; cyanamidothioxanthate; phenyl thioxanthate (PhSxan); benzyl thioxanthate (BzSxan); pentafluorophenyl thioxanthate; cyclohexyl thioxanthate (cHxSxan); and norbornyl thioxanthate. [Note: thioxanthates tend to stabilize lower oxidation states in metal ions.]

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S Valence Stabilizer #41: Examples of xanthates, bis(xanthates), and poly(xanthates) (S-S Bidentates and S-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl xanthate (Mexan); ethyl xanthate (Etxan); isopropyl xanthate (iPrxan); trifluoromethyl xanthate (CF_3 xan); cyanoxanthate; cyanamidoxanthate; phenyl xanthate (Phxan); benzyl xanthate (Bzxan); pentafluorophenyl xanthate; cyclohexyl xanthate (cHxxan); and norbornyl xanthate. [Note: xanthates tend to stabilize lower oxidation states in metal ions.]

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S Valence Stabilizer #42: Examples of phosphinodithioformates (S-S Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trimethylphosphinodithioformate; triethylphosphinodithioformate; triphenylphosphinodithioformate; tricyclohexylphosphinodithioformate; dimethylphosphinodithioformate; diethylphosphinodithioformate; diphenylphosphinodithioformate; and dicyclohexylphosphinodithioformate.

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S Valence Stabilizer #43: Examples of alkyl- and aryl- dithioborates, trithioborates, perthioborates, bis(dithioborates), bis(trithioborates), and bis(perthioborates) (S-S Bidentates and S-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for

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Ce⁺⁴ include, but are not limited to: S,O-diethyl dithioborate; S,O-diisopropyl dithioborate; S,O-diphenyl dithioborate; S,O-dibenzyl dithioborate; S,O-dicyclohexyl dithioborate; S,O-dinorbornyl dithioborate; diethyl trithioborate; diisopropyl trithioborate; diphenyl trithioborate; dibenzyl trithioborate; dicyclohexyl trithioborate; and dinorbornyl trithioborate.

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S Valence Stabilizer #44: Examples of alkyl- and aryl- dithioboronates and bis(dithioboronates) (S-S Bidentates and S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: diethyl dithioboronate; diisopropyl dithioboronate; diphenyl dithioboronate; dibenzyl dithioboronate; dicyclohexyl dithioboronate; and dinorbornyl dithioboronate. [Note: boronates tend to stabilize lower oxidation states in metal ions.]

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S Valence Stabilizer #45: Examples of trithioarsonic acids (arsonotrithioic acids), dithioarsonic acids (arsonodithioic acids), tetrathioarsonic acids (arsonotetrathioic acids), and derivatives

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thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: trithioarsonic acid, O-phenyltrithioarsonic acid, O-benzyltrithioarsonic acid, O-cyclohexyltrithioarsonic acid, O-norbornyltrithioarsonic acid, O,S-diphenyltrithioarsonic acid, O,S-dibenzyltrithioarsonic acid, O,S-dicyclohexyltrithioarsonic acid, O,S-dinorbornyltrithioarsonic acid; dithioarsonic acid, O-phenyldithioarsonic acid, O-benzyl dithioarsonic acid, O-cyclohexyldithioarsonic acid, O-norbornyldithioarsonic acid, O,O-diphenyldithioarsonic acid, O,O-dibenzyl dithioarsonic acid, O,O-dicyclohexyldithioarsonic acid, and O,O-dinorbornyldithioarsonic acid.

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S Valence Stabilizer #46: Examples of trithioantimonic acids (stibonotrithioic acids),

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dithioantimonic acids (stibonodithioic acids), tetrathioantimonic acids (stibonotetrathioic acids), and derivatives thereof (S-S Bidentates, S-S Tridentates, S-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: trimethyltrithioantimonate; triethyltrithioantimonate; and triphenyltrithioantimonate.

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S Valence Stabilizer #47: Examples of phosphine P-sulfides and amino-substituted phosphine sulfides (S Monodentates) that meet the requirements for use as “narrow band” valence

stabilizers for Ce^{+4} include, but are not limited to: trimethylphosphine sulfide (TMPS); triethylphosphine sulfide (TEPS); triphenylphosphine sulfide (TPhPS); tribenzylphosphine sulfide (TBzPS); tricyclohexylphosphine sulfide (TcHxPS); and trinorbornylphosphine sulfide for phosphine P-sulfides; and tris(dimethylamino)phosphine sulfide; trimorpholinophosphine sulfide; tripiperidinophosphine sulfide; tripyrrolidinophosphine sulfide; and tri(cyclohexylamino)phosphine sulfide for amino-substituted phosphine sulfides.

S Valence Stabilizer #48: Examples of arsine As-sulfides and amino-substituted arsine sulfides (S Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trimethylarsine sulfide; triethylarsine sulfide; triphenylarsine sulfide; tribenzylarsine sulfide; tricyclohexylarsine sulfide; and trinorbornylarsine sulfide for arsine As-sulfides; and tris(dimethylamino)arsine sulfide; trimorpholinoarsine sulfide; tripiperidinoarsine sulfide; tripyrrolidinoarsine sulfide; and tri(cyclohexylamino)arsine sulfide for amino-substituted arsine sulfides.

S Valence Stabilizer #49: Examples of thiolates that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiophenol; naphthalenethiol; 1-dodecanethion; hexadecyl mercaptan; benzenethiol (bt); polybenzenethiols; and polythioarylenes.

S Valence Stabilizer #50: Examples of sulfide that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: sulfides ($-S^{2-}$); disulfides ($-S_2^{2-}$); and polysulfides ($-S_x^{2-}$).

P Valence Stabilizer #1: Examples of monophosphines (P monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphine, phenylphosphine, diphenylphosphine, triphenylphosphine, tricyclohexylphosphine, phenyldimethylphosphine, phenyldiethylphosphine, methyldiphenylphosphine, ethyldiphenylphosphine, phosphirane, phosphetane, phospholane, phosphorinane, benzophospholane, benzophosphorinane, dibenzophospholane, dibenzophosphorinane, naphthophospholane, naphthophosphorinane, phosphinonorbornane, and phosphinoadamantane.

P Valence Stabilizer #2: Examples of diphosphines (P monodentates or P-P bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphospholane, benzodiphospholane, naphthodiphospholane, diphosphorinane, benzodiphosphorinane, dibenzodiphosphorinane, naphthodiphosphorinane,

- 5 bis(diphenylphosphino)methane, bis(diphenylphosphino)ethane, bis(diphenylphosphino)propane, bis(diphenylphosphino)butane, bis(diphenylphosphino)pentane, 1,2-bis(diphenylphosphino)ethylene, and o-phenylenebis(diphenylphosphine). [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

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P Valence Stabilizer #3: Examples of triphosphines (P monodentates, P-P bidentates, or P-P tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: triphosphorinane, P,P'-tetraphenyl-2-methyl-2-(P-diphenyl)phosphinomethyl-1,3-propanediphosphine; P,P-[2-(P-diphenyl)phosphinoethyl]diethyl-
15 P-phenylphosphine; P,P-[2-(P-diphenyl)phosphino]diphenyl-P-phenylphosphine; and hexahydro-2,4,6-trimethyl-1,3,5-triphosphazine. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

- P Valence Stabilizer #4: Examples of tetraphosphines (P monodentates, P-P bidentates, P-P tridentates, and P-P tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: P,P'-tetraphenyl-2,2-[(P-diphenyl)phosphinomethyl]-1,3-propanediphosphine; tri[o-(P-diphenyl)phosphinophenyl]phosphine; and 1,1,4,7,10,10-hexaphenyl-1,4,7,10-tetraphosphadecane. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are
20 air-sensitive and therefore unsuitable for these applications.]

- P Valence Stabilizer #5: Examples of pentaphosphines (P monodentates, P-P bidentates, P-P tridentates, and P-P tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-[2-(P-diphenyl)phosphinoethyl]-1,1,7,10,10-pentaphenyl-1,4,7,10-tetraphosphadecane. [Note: the aryl derivatives are air-stable, whereas the
30 alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

P Valence Stabilizer #6: Examples of hexaphosphines (P-P bidentates, P-P tridentates, P-P tetradentates, and P-P hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,1,10,10-tetraphenyl-4,7-[2-(P,P-diphenyl)phosphinoethyl]-1,4,7,10-tetraphosphadecane. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

P Valence Stabilizer #7a: Examples of 5-membered heterocyclic rings containing one phosphorus atom (P monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1-phospholene, 2-phospholene, 3-phospholene, phosphole, oxaphosphole, thiaphosphole, benzophospholene, benzophosphole, benzoxaphosphole, benzothiaphosphole, dibenzophospholene, dibenzophosphole, naphthophospholene, naphthophosphole, naphthoxaphosphole, naphthothiaphosphole.

P Valence Stabilizer #7b: Examples of 5-membered heterocyclic rings containing two phosphorus atoms (P monodentates or P-P bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphospholene, diphosphole, oxadiphospholene, thiadiphospholene, benzodiphospholene, benzodiphosphole, naphthodiphospholene, and naphthodiphosphole.

P Valence Stabilizer #7c: Examples of 5-membered heterocyclic rings containing three phosphorus atoms (P monodentates or P-P bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: triphosphole.

P Valence Stabilizer #8a: Examples of 6-membered heterocyclic rings containing one phosphorus atom (P monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphorin, oxaphosphorin, thiaphosphorin, benzophosphorin, benzoxaphosphorin, benzothiaphosphorin, acridophosphine, phosphanthridine, dibenzoxaphosphorin, dibenzothiaphosphorin, naphthophosphorin, naphthoxaphosphorin, and naphthothiaphosphorin.

P Valence Stabilizer #8b: Examples of 6-membered heterocyclic rings containing two phosphorus atoms (P monodentates or P-P bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: o-diphosphorin, m-diphosphorin, p-diphosphorin, oxadiphosphorin, thiadiphosphorin, benzodiphosphorin, benzoxadiphosphorin, benzothiadiphosphorin, dibenzodiphosphorin, dibenzoxadiphosphorin, dibenzothiadiphosphorin, naphthodiphosphorin, naphthoxadiphosphorin, and naphthothiadiphosphorin.

P Valence Stabilizer #8c: Examples of 6-membered heterocyclic rings containing three phosphorus atoms (P monodentates or P-P bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,3,5-triphosphorin, 1,2,3-triphosphorin, benzo-1,2,3-triphosphorin, and naphtho-1,2,3-triphosphorin.

P Valence Stabilizer #9a: Examples of 5-membered heterocyclic rings containing one phosphorus atom and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)-1-phospholene; 2,5-(P-phenylphosphino)-1-phospholene; 2-(P-phenylphosphino)-3-phospholene; 2,5-(P-phenylphosphino)-3-phospholene; 2-(P-phenylphosphino)phosphole; 2,5-(P-phenylphosphino)phosphole; 2-(P-phenylphosphino)benzophosphole; 7-(P-phenylphosphino)benzophosphole; and 1,8-(P-phenylphosphino)dibenzophosphole..

P Valence Stabilizer #9b: Examples of 5-membered heterocyclic rings containing two phosphorus atoms and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)-1,3-diphospholene; 2,5-(P-phenylphosphino)-1,3-diphospholene; 2-(P-phenylphosphino)-1,3-diphosphole; 2,5-(P-phenylphosphino)-1,3-diphosphole; 2-(P-phenylphosphino)benzodiphosphole; and 7-(P-phenylphosphino)benzodiphosphole.

P Valence Stabilizer #9c: Examples of 5-membered heterocyclic rings containing three phosphorus atoms and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)-1,3,4-triphosphole; and 2,5-(P-phenylphosphino)-1,3,4-triphosphole.

P Valence Stabilizer #10a: Examples of 6-membered heterocyclic rings containing one phosphorus atom and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)phosphorin; 2,5-(P-phenylphosphino)phosphorin; 2-(P-phenylphosphino)benzophosphorin; 7-(P-phenylphosphino)benzophosphorin; and 1,9-(P-phenylphosphino)acridophosphine.

P Valence Stabilizer #10b: Examples of 6-membered heterocyclic rings containing two phosphorus atoms and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)-4-diphosphorin; 2,6-(P-phenylphosphino)-4-diphosphorin; 2,3,5,6-(P-phenylphosphino)-4-diphosphorin; 2-(P-phenylphosphino)benzo-1,4-diphosphorin; 2,3-(P-phenylphosphino)benzo-1,4-diphosphorin; 2,8-(P-phenylphosphino)benzo-1,4-diphosphorin; 2,3,5,8-(P-phenylphosphino)benzo-1,4-diphosphorin; 1,9-(P-phenylphosphino)dibenzodiphosphorin; and 1,4,6,9-(P-phenylphosphino)dibenzodiphosphorin.

P Valence Stabilizer #10c: Examples of 6-membered heterocyclic rings containing three phosphorus atoms and having at least one additional phosphorus atom binding site not contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(P-phenylphosphino)-1,3,5-triphosphorin; 2,6-(P-

phenylphosphino)-1,3,5-triphosphorin; 4-(P-phenylphosphino)-1,2,3-triphosphorin; and 8-(P-phenylphosphino)benzo-1,2,3-triphosphorin.

P Valence Stabilizer #11a: Examples of 5-membered heterocyclic rings containing one

- 5 phosphorus atom and having at least one additional phosphorus atom binding site contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2’-bi-1-phospholene; 2,2’,2’’-tri-1-phospholene; 2,2’-bi-3-phospholene; 2,2’, 2’’-tri-3-phospholene; 2,2’-biphosphole; 2,2’,2’’-triphosphole; and 2,2’-bibenzophosphole.

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P Valence Stabilizer #11b: Examples of 5-membered heterocyclic rings containing two

phosphorus atoms and having at least one additional phosphorus atom binding site contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 15 2,2’-bi-1,3-diphospholene; 2,2’-bi-1,3-diphosphole; and 2,2’-bibenzo-1,3-diphosphole.

P Valence Stabilizer #11c: Examples of 5-membered heterocyclic rings containing three

phosphorus atoms and having at least one additional phosphorus atom binding site contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the

- 20 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2’-bi-1,3,4-triphosphole; and 2,2’,2’’-tri-1,3,4-triphosphole.

P Valence Stabilizer #12a: Examples of 6-membered heterocyclic rings containing one

phosphorus atom and having at least one additional phosphorus atom binding site contained in a

- 25 ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2’-biphosphorin; 2,2’,2’’-triphosphorin; 2,2’,2’’,2’’’-tetraphosphorin; 2,2’-bibenzophosphorin; and 8,8’-bibenzophosphorin.

30 P Valence Stabilizer #12b: Examples of 6-membered heterocyclic rings containing two

phosphorus atoms and having at least one additional phosphorus atom binding site contained in a

ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 3,3'-bi-1,2-diphosphorin; 3,3',3''-tri-1,2-diphosphorin; 2,2'-bi-1,4-diphosphorin; 2,2',2''-tri-1,4-diphosphorin; 3,3'-bibenzo-1,2-diphosphorin; 8,8'-bibenzo-1,2-diphosphorin; 2,2'-bibenzo-1,4-diphosphorin; and 8,8'-bibenzo-1,4-diphosphorin.

P Valence Stabilizer #12c: Examples of 6-membered heterocyclic rings containing three phosphorus atoms and having at least one additional phosphorus atom binding site contained in a ring (P Monodentates, P-P Bidentates, P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-1,3,5-triphosphorin; 2,2',2''-tri-1,3,5-triphosphorin; 4,4'-bi-1,2,3-triphosphorin; 4,4'-bibenzo-1,2,3-triphosphorin; and 8,8'-bibenzo-1,2,3-triphosphorin.

P Valence Stabilizer #13a: Examples of two-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein both binding sites are composed of phosphorus and are not contained in component heterocyclic rings (P-P Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: P,P-diphenyldiphosphacyclobutane ([4]aneP₂); P,P-diphenyldiphosphacyclopentane ([5]aneP₂); P,P-diphenyldiphosphacyclohexane ([6]aneP₂); P,P-diphenyldiphosphacycloheptane ([7]aneP₂); P,P-diphenyldiphosphacyclooctane ([8]aneP₂); P,P-diphenyldiphosphacyclobutene ([4]eneP₂); P,P-diphenyldiphosphacyclopentene ([5]eneP₂); P,P-diphenyldiphosphacyclohexene ([6]eneP₂); P,P-diphenyldiphosphacycloheptene ([7]eneP₂); and P,P-diphenyldiphosphacyclooctene ([8]eneP₂).

P Valence Stabilizer #13b: Examples of three-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of phosphorus and are not contained in component heterocyclic rings (P-P Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: P,P,P-triphenyltriphosphacyclohexane ([6]aneP₃); P,P,P-triphenyltriphosphacycloheptane ([7]aneP₃); P,P,P-triphenyltriphosphacyclooctane ([8]aneP₃); P,P,P-triphenyltriphosphacyclononane ([9]aneP₃); P,P,P-triphenyltriphosphacyclodecane

([10]aneP₃); P,P,P-triphenyltriposphacycloundecane ([11]aneP₃); P,P,P-triphenyltriposphacyclododecane ([12]aneP₃); P,P,P-triphenyltriposphacyclohexatriene ([6]trieneP₃); P,P,P-triphenyltriposphacycloheptatriene ([7]trieneP₃); P,P,P-triphenyltriposphacyclooctatriene ([8]trieneP₃); P,P,P-triphenyltriposphacyclononatriene ([9]trieneP₃); P,P,P-triphenyltriposphacyclodecatriene ([10]trieneP₃); P,P,P-triphenyltriposphacycloundecatriene ([11]trieneP₃); and P,P,P-triphenyltriposphacyclododecatriene ([12]trieneP₃).

P Valence Stabilizer #13c: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cydidenes, and sepulchrates) wherein all binding sites are composed of phosphorus and are not contained in component heterocyclic rings (P-P Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: P,P,P,P-tetraphenyltetraphosphacyclooctane ([8]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclononane ([9]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclodecane ([10]aneP₄); P,P,P,P-tetraphenyltetraphosphacycloundecane ([11]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclododecane ([12]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclotridecane ([13]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclotetradecane ([14]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclopentadecane ([15]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclohexadecane ([16]aneP₄); P,P,P,P-tetraphenyltetraphosphacycloheptadecane ([17]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclooctadecane ([18]aneP₄); P,P,P,P-tetraphenyltetraphosphacyclononadecane ([19]aneP₄); and P,P,P,P-tetraphenyltetraphosphacycloeicosane ([20]aneP₄).

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P Valence Stabilizer #13d: Examples of five-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of phosphorus and are not contained in component heterocyclic rings (P-P Tridentates, or P-P Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: P,P,P,P,P-pentaphenylpentaphosphacyclodecane ([10]aneP₅); P,P,P,P,P-

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- pentaphenylpentaphosphacycloundecane ([11]aneP₅); P,P,P,P,P-
pentaphenylpentaphosphacyclododecane ([12]aneP₅); P,P,P,P,P-
pentaphenylpentaphosphacyclotridecane ([13]aneP₅); P,P,P,P,P-
pentaphenylpentaphosphacyclotetradecane ([14]aneP₅); and P,P,P,P,P-
5 pentaphenylpentaphosphacyclopentadecane ([15]aneP₅).

- P Valence Stabilizer #13e: Examples of six-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of phosphorus and are not contained in component heterocyclic rings
10 (P-P-P Tridentates, P-P-P-P Tetracentates, or P-P-P-P-P Hexacentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
P,P,P,P,P,P-hexaphenylhexaphosphacyclododecane ([12]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclotridecane ([13]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclotetradecane ([14]aneP₆); P,P,P,P,P,P-
15 hexaphenylhexaphosphacyclopentadecane ([15]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclohexadecane ([16]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacycloheptadecane ([17]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclooctadecane ([18]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclononadecane ([19]aneP₆); P,P,P,P,P,P-
20 hexaphenylhexaphosphacycloeicosane ([20]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacycloheneicosane ([21]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclodocosane ([22]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclotricosane ([23]aneP₆); P,P,P,P,P,P-
hexaphenylhexaphosphacyclotetracosane ([24]aneP₆).

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- P Valence Stabilizer #13f: Examples of eight-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of phosphorus and are not contained in component heterocyclic rings
(P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as
30 “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: P,P,P,P,P,P,P,P-
octaphenyloctaphosphacyclohexadecane ([16]aneP₈); P,P,P,P,P,P,P,P-

- octaphenyloctaphosphacycloheptadecane ([17]aneP₈); P,P,P,P,P,P,P-P-
octaphenyloctaphosphacyclooctadecane ([18]aneP₈); P,P,P,P,P,P,P-P-
octaphenyloctaphosphacyclononadecane ([19]aneP₈); P,P,P,P,P,P,P-P-
octaphenyloctaphosphacycloeicosane ([20]aneP₈); P,P,P,P,P,P,P-P-
5 octaphenyloctaphosphacycloheneicosane ([21]aneP₈); P,P,P,P,P,P,P-P-
octaphenyloctaphosphacyclodocosane ([22]aneP₈); P,P,P,P,P,P,P-P-
octaphenyloctaphosphacyclotricosane ([23]aneP₈); and P,P,P,P,P,P,P-P-
octaphenyloctaphosphacyclotetracosane ([24]aneP₈).
- 10 P Valence Stabilizer #14a: Examples of four-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
four binding sites are composed of phosphorus and are contained in component 5-membered
heterocyclic rings (P-P Tetracentates) that meet the requirements for use as “narrow band”
valence stabilizers for Ce⁺⁴ include, but are not limited to: tetraphospholenes; tetraphospholes;
15 tetraoxaphospholes; tetradiphospholenes; tetradiphospholes; and tetraoxadiphospholes.
- P Valence Stabilizer #14b: Examples of six-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
six binding sites are composed of phosphorus and are contained in component 5-membered
20 heterocyclic rings (P-P Tetracentates and P-P Hexacentates) that meet the requirements for use
as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: hexaphospholenes;
hexaphospholes; hexaaxaphospholes; hexadiphospholenes; hexadiphospholes; and
hexaaxadiphospholes.
- 25 P Valence Stabilizer #14c: Examples of eight-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
eight binding sites are composed of phosphorus and are contained in component 5-membered
heterocyclic rings (P-P Tridentates; P-P Tetracentates; or P-P Hexacentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
30 octaphospholenes; octaphospholes; octaaxaphospholes; octadiphospholenes; octadiphospholes;
and octaaxadiphospholes.

P Valence Stabilizer #15a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of phosphorus and are contained in a combination of 5-membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosphatetraphospholenes; tetraphosphatetraphospholenes; diphosphatetraphospholes; tetraphosphatetraphospholes; diphosphatetradiphospholes; and tetraphosphatetradiphospholes.

10 P Valence Stabilizer #15b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of phosphorus and are contained in a combination of 5-membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetracentates, and P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosphahexaphospholenes; triphosphahexaphospholenes; diphosphahexaphospholes; triphosphahexaphospholes; diphosphahexadiphospholes; and triphosphahexadiphospholes.

20 P Valence Stabilizer #15c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of phosphorus and are contained in a combination of 5-membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetracentates, and P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosphaoctaphospholenes; tetraphosphaoctaphospholenes; diphosphaoctaphospholes; tetraphosphaoctaphospholes; diphosphaoctadiphospholes; and tetraphosphaoctadiphospholes.

30 P Valence Stabilizer #16a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of phosphorus and are contained in component 6-membered heterocyclic rings (P-P Tetracentates) that meet the requirements for use as “narrow band”

valence stabilizers for Ce^{+4} include, but are not limited to: cyclotetraphosphorins; cyclotetraoxaphosphorins; cyclotetradiphosphorins; and cyclotetraoxadiphosphorins.

P Valence Stabilizer #16b: Examples of six-membered macrocyclics, macrobicyclics, and

- 5 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of phosphorus and are contained in component 6-membered heterocyclic rings (P-P Tridentates, P-P Tetracentates, and P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclohexaphosphorins; cyclohexaaxaphosphorins; cyclohexadiphosphorins; and
10 cyclohexaaxadiphosphorins.

P Valence Stabilizer #16c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of phosphorus and are contained in component 6-membered

- 15 heterocyclic rings (P-P Tridentates, P-P Tetracentates, and P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclooctaphosphorins; cyclooctaaxaphosphorins; cyclooctadiphosphorins; and cyclooctaaxadiphosphorins.

P Valence Stabilizer #17a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of phosphorus and are contained in a combination of 6-membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetracentates, or P-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4}

- 25 include, but are not limited to: diphosphacyclotetraphosphorins; tetraphosphacyclotetraphosphorins; diphosphacyclotetraoxaphosphorins; tetraphosphacyclotetraoxaphosphorins; diphosphacyclotetradiphosphorins; tetraphosphacyclotetradiphosphorins; diphosphacyclotetraoxadiphosphorins; and tetraphosphacyclotetraoxadiphosphorins.

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P Valence Stabilizer #17b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of phosphorus and are contained in a combination of 6-membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetradentates, or P-P

- 5 Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosphacyclohexaphosphorins;
triphosphacyclohexaphosphorins; diphosphacyclohexaoxaphosphorins;
triphosphacyclohexaoxaphosphorins; diphosphacyclohexadiphosphorins;
triphosphacyclohexadiphosphorins; diphosphacyclohexaoxadiphosphorins; and
10 triphosphacyclohexaoxadiphosphorins.

P Valence Stabilizer #17c: Examples of eight-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all eight binding sites are composed of phosphorus and are contained in a combination of 6-

- 15 membered heterocyclic rings and phosphine groups (P-P Tridentates, P-P Tetradentates, or P-P Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosphacyclooctaphosphorins;
tetraphosphacyclooctaphosphorins; diphosphacyclooctaoxaphosphorins;
tetraphosphacyclooctaoxaphosphorins; diphosphacyclooctadiphosphorins;
20 tetraphosphacyclooctadiphosphorins; diphosphacyclooctaoxadiphosphorins; and
tetraphosphacyclooctaoxadiphosphorins.

O Valence Stabilizer #1: Examples of dithioperoxydicarbonic acids, bis(dithioperoxydicarbonic acids), poly(dithioperoxydicarbonic acids), and derivatives thereof (O-O Bidentates, O-O

- 25 Tridentates, O-O Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithioperoxydicarbonic acid, O-phenyldithioperoxydicarbonic acid; O-benzoyldithioperoxydicarbonic acid; O-cyclohexyldithioperoxydicarbonic acid; O-norbornyldithioperoxydicarbonic acid; O,O'-diphenyldithioperoxydicarbonic acid; O,O'-dibenzoyldithioperoxydicarbonic acid; O,O'-dicyclohexyldithioperoxydicarbonic acid; and O,O'-dinorbornyldithioperoxydicarbonic acid.
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O Valence Stabilizer #2: Examples of imidodiphosphonic acids, hydrazidodiphosphonic acids, bis(imidodiphosphonic acids), bis(hydrazidodiphosphonic acids), poly(imidodiphosphonic acids), poly(hydrazidodiphosphonic acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “narrow band” valence

5 stabilizers for Ce^{+4} include, but are not limited to: imidodiphosphonic acid, methylimidodiphosphonic acid, isopropylimidodiphosphonic acid, tert-butylimidodiphosphonic acid, phenylimidodiphosphonic acid, pentafluorophenylimidodiphosphonic acid, benzylimidodiphosphonic acid, cyclohexylimidodiphosphonic acid, norbornylimidodiphosphonic acid, dimethylimidodiphosphonic acid, diisopropylimidodiphosphonic acid, di-tert-
10 butylimidodiphosphonic acid, diphenylimidodiphosphonic acid, di-pentafluorophenylimidodiphosphonic acid, dibenzylimidodiphosphonic acid, dicyclohexylimidodiphosphonic acid, and dinorbornylimidodiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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O Valence Stabilizer #3: Examples of imidodiphosphonamides, hydrazidodiphosphonamides, bis(imidodiphosphonamides), bis(hydrazidodiphosphonamides), poly(imidodiphosphonamides), and poly(hydrazidodiphosphonamides) (O-O Bidentates, O-O Tridentates, O-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are

20 not limited to: imidodiphosphonamide, N-methylimidodiphosphonamide, N-isopropylimidodiphosphonamide, N-tert-butylimidodiphosphonamide, N-phenylimidodiphosphonamide, N-pentafluorophenylimidodiphosphonamide, N-benzylimidodiphosphonamide, N-cyclohexylimidodiphosphonamide, N-norbornylimidodiphosphonamide, N,N'''-dimethylimidodiphosphonamide, N,N'''-
25 diisopropylimidodiphosphonamide, N,N'''-di-tert-butylimidodiphosphonamide, N,N'''-diphenylimidodiphosphonamide, N,N'''-di-pentafluorophenylimidodiphosphonamide, N,N'''-dibenzylimidodiphosphonamide, N,N'''-dicyclohexylimidodiphosphonamide, and N,N'''-dinorbornylimidodiphosphonamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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O Valence Stabilizer #4: Examples of diphosponamides, bis(diphosponamides), and poly(diphosponamides) (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphosponamide, N-methyldiphosponamide, N-isopropyldiphosponamide, N-tert-

- 5 butyldiphosponamide, N-phenyldiphosponamide, N-pentafluorophenyldiphosponamide, N-benzyldiphosponamide, N-cyclohexyldiphosponamide, N-norbornyldiphosponamide, N,N'''-dimethyldiphosponamide, N,N'''-diisopropyldiphosponamide, N,N'''-di-tert-butyldiphosponamide, N,N'''-diphenyldiphosponamide, N,N'''-di-pentafluorophenyldiphosponamide, N,N'''-dibenzyldiphosponamide, N,N'''-dicyclohexyldiphosponamide, and N,N'''-dinorbornyldiphosponamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

O Valence Stabilizer #5: Examples of carbazates (carbazides), bis(carbazates), and

- 15 poly(carbazates) (O-O Bidentates, O-O Tridentates, and O-O Tetridentates; or possibly N-O Bidentates, N-O Tridentates, and N-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-dimethylcarbazate; N,N'-di(trifluoromethyl)carbazate; N,N'-diethylcarbazate; N,N'-diphenylcarbazate; N,N'-dibenzylcarbazate; N,N'-di(pentafluorophenyl)carbazate; N,N'-dicyclohexylcarbazate; and N,N'-dinorbornylcarbazate.

O Valence Stabilizer #6: Examples of arsonic acids, bis(arsonic acids), poly(arsonic acids), and derivatives thereof (O-O Bidentates, O-O Tridentates, O-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 25 arsonic acid, O-phenylarsonic acid, O-benzylarsonic acid, O-cyclohexylarsonic acid, O-norbornylarsonic acid, O,O-diphenylarsonic acid, O,O-dibenzylarsonic acid, O,O-dicyclohexylarsonic acid, O,O-dinorbornylarsonic acid, and aminophenylarsonic acids.

O Valence Stabilizer #7: Examples of alkyl- and aryl- borates and bis(borates) (O-O Bidentates

- 30 and O-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers

for Ce^{+4} include, but are not limited to: triethyl borate; diisopropyl borate; diphenyl borate; dibenzyl borate; dicyclohexyl borate; and dinorbornyl borate.

O Valence Stabilizer #8: Examples of alkyl- and aryl- boronates and bis(boronates) (O-O

- 5 Bidentates and O-O Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diethyl boronate; diisopropyl boronate; diphenyl boronate; dibenzyl boronate; dicyclohexyl boronate; and dinorbornyl boronate. [Note: boronates tend to stabilize lower oxidation states in metal ions.]

- 10 O Valence Stabilizer #9: Examples of phosphine P-oxides and amino-substituted phosphine oxides (O Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trimethylphosphine oxide (TMPO); triethylphosphine oxide (TEPO); triphenylphosphine oxide (TPhPO); tribenzylphosphine oxide (TBzPO); tricyclohexylphosphine oxide (TcHxPO); and trinorbornylphosphine oxide for phosphine P-
- 15 oxides; and hexamethylphosphoramide (HMPA); trimorpholinophosphine oxide (TMrPO); tripiperidinophosphine oxide; tripyrrolidinophosphine oxide; and tri(cyclohexylamino)phosphine oxide for amino-substituted phosphine oxides.

O Valence Stabilizer #10: Examples of arsine As-oxides and amino-substituted arsine oxides (O

- 20 Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trimethylarsine oxide (TMAsO); triethylarsine oxide (TEAsO); triphenylarsine oxide (TPhAsO); tribenzylarsine oxide (TBzAsO); tricyclohexylarsine oxide (TcHxAsO); and trinorbornylarsine oxide for arsine As-oxides; and hexamethylarsonamide; trimorpholinoarsine oxide; tripiperidinoarsine oxide; tripyrrolidinoarsine oxide; and
- 25 tri(cyclohexylamino)arsine oxide for amino-substituted arsine oxides.

O Valence Stabilizer #11a: Examples of 5-membered heterocyclic rings containing one oxygen atom (O monodentate) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: furan, dihydrofuran, oxazole, isoxazole, oxadiazole,

30 oxatriazole, oxathiole, benzofuran, benzodihydrofuran, benzoxazole, benzisoxazole, benzoxadiazole (benzofurazan), dibenzofuran, dibenzoxazole, dibenzisoxazole, naphthofuran,

naphthoxazole, naphthisoxazole, and naphthoxadiazole.

O Valence Stabilizer #11b: Examples of 5-membered heterocyclic rings containing two oxygen atoms (O monodentate or O-O bidentates) that meet the requirements for use as “narrow band”

- 5 valence stabilizers for Ce^{+4} include, but are not limited to: dioxolane, benzodioxolane, and naphthodioxolane.

O Valence Stabilizer #12a: Examples of 6-membered heterocyclic rings containing one oxygen atom (O monodentate) that meet the requirements for use as “narrow band” valence stabilizers

- 10 for Ce^{+4} include, but are not limited to: dihydropyran, pyran, oxazine, oxadiazine, oxatriazine, oxathiin, benzopyran, benzoxazine, benzoxadiazine, dibenzopyran, naphthopyran, naphthoxazine, and naphthoxadiazine.

O Valence Stabilizer #12b: Examples of 6-membered heterocyclic rings containing two oxygen

- 15 atoms (O monodentate or O-O bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydrodioxane, dioxane, benzodioxane, dibenzodioxane, and naphthodioxane.

O Valence Stabilizer #13a: Examples of 5-membered heterocyclic rings containing one oxygen

- 20 atom and having at least one additional oxygen atom binding site not contained in a ring (O monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,5-dihydroxy-2,5-dihydrofuran; 2,5-bis(hydroxymethyl)-2,5-dihydrofuran; 2,5-bis(2-hydroxyphenyl)-2,5-dihydrofuran; 2,5-dihydroxyfuran; 2,5-bis(hydroxymethyl)furan; and 2,5-
25 bis(2-hydroxyphenyl)furan.

O Valence Stabilizer #13b: Examples of 5-membered heterocyclic rings containing two oxygen atoms and having at least one additional oxygen atom binding site not contained in a ring (O monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that

- 30 meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxy-1,3-dioxolane; 2-hydroxymethyl-1,3-dioxolane; 4,5-dihydroxy-1,3-

dioxolane; 4,5-bis(2-hydroxyphenyl)-1,3-dioxolane; 2-hydroxybenzodioxolane; and 7-hydroxybenzodioxolane.

O Valence Stabilizer #14a: Examples of 6-membered heterocyclic rings containing one oxygen

5 atom and having at least one additional oxygen atom binding site not contained in a ring (O monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,6-dihydroxy-2,5-dihdropyran; 2,6-bis(hydroxymethyl)-2,5-dihdropyran; 2,6-bis(2-hydroxyphenyl)-2,5-dihdropyran; 2,6-dihdropyran; 2,6-bis(hydroxymethyl)pyran; 2,6-
10 bis(2-hydroxyphenyl)pyran; 2-hydroxy-1-benzopyran; 8-hydroxy-1-benzopyran; and 1,9-dihydroxydibenzopyran.

O Valence Stabilizer #14b: Examples of 6-membered heterocyclic rings containing two oxygen atoms and having at least one additional oxygen atom binding site not contained in a ring (O

15 monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxy-1,4-dioxane; 2,6-dihydroxy-1,4-dioxane; 2,6-bis(2-hydroxyphenyl)-1,4-dioxane; 2,3-dihydroxy-1,4-benzodioxane; 5,8-dihydroxy-1,4-benzodioxane; 1,8-dihydroxydibenzodioxane; and 1,4,5,8-tetrahydroxydibenzodioxane.

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O Valence Stabilizer #15a: Examples of 5-membered heterocyclic rings containing one oxygen atom and having at least one additional oxygen atom binding site contained in a ring (O

monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not
25 limited to: 2,2'-bi-2,5-dihydrofuran; 2,2',2''-tri-2,5-dihydrofuran; 2,2'-bifuran; 2,2',2''-trifuran; 1,1'-bis(dibenzofuran); and polyfurans.

O Valence Stabilizer #15b: Examples of 5-membered heterocyclic rings containing two oxygen atoms and having at least one additional oxygen atom binding site contained in a ring (O

30 monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not

limited to: 2,2'-bi-1,3-dioxolane; 4,4'-bi-1,3-dioxolane; 7,7'-bi-1,2-benzodioxolane; and 3,3'-bi-1,2-benzodioxolane.

O Valence Stabilizer #16a: Examples of 6-membered heterocyclic rings containing one oxygen

- 5 atom and having at least one additional oxygen atom binding site contained in a ring (O monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2,5-dihydropyran; 2,2',2''-tri-2,5-dihydropyran; 2,2'-bipyran; 2,2',2''—tripyrans; and 1,1'-bis(dibenzopyran).

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O Valence Stabilizer #16b: Examples of 6-membered heterocyclic rings containing one oxygen

- atom and having at least one additional oxygen atom binding site contained in a ring (O monodentates, O-O bidentates, O-O tridentates, O-O tetradentates, or O-O hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-1,4-dioxane; 2,2'-bi-1,3-dioxane; 5,5'-bi-1,4-benzodioxane; and 2,2'-bi-1,3-benzodioxane.

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O Valence Stabilizer #17a: Examples of four-membered macrocyclics, macrobicyclics, and

- macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetradentates, and O-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 8-crown-4; 10-crown-4; 12-crown-4; 14-crown-4; 16-crown-4; 18-crown-4; 20-crown-4; dibenzo-8-crown-4; dibenzo-10-crown-4; dibenzo-12-crown-4; 25 dibenzo-14-crown-4; dibenzo-16-crown-4; dibenzo-18-crown-4; dibenzo-20-crown-4; tetrabenzo-8-crown-4; tetrabenzo-10-crown-4; tetrabenzo-12-crown-4; tetrabenzo-14-crown-4; tetrabenzo-16-crown-4; tetrabenzo-18-crown-4; and tetrabenzo-20-crown-4.

O Valence Stabilizer #17b: Examples of five-membered macrocyclics, macrobicyclics, and

- 30 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in

component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 10-crown-5; 15-crown-5; 20-crown-5; 25-crown-5; pentabenz-10-crown-5; pentabenz-15-crown-5; pentabenz-20-crown-5; and pentabenz-25-crown-5.

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O Valence Stabilizer #17c: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O

10 Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 12-crown-6; 18-crown-6; 24-crown-6; 30-crown-6; 36-crown-6; tribenz-12-crown-6; tribenz-18-crown-6; tribenz-24-crown-6; tribenz-30-crown-6; tribenz-36-crown-6; hexabenz-12-crown-6; hexabenz-18-crown-6; hexabenz-24-crown-6; hexabenz-30-crown-6; and hexabenz-36-crown-6.

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O Valence Stabilizer #17d: Examples of seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O

20 Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 14-crown-7; 21-crown-7; 28-crown-7; 35-crown-7; heptabenz-14-crown-7; heptabenz-21-crown-7; heptabenz-28-crown-7; and heptabenz-35-crown-7.

O Valence Stabilizer #17e: Examples of eight-membered macrocyclics, macrobicyclics, and

25 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 16-crown-8; 24-crown-8; 32-crown-8; 40-crown-8; 48-crown-8;

30 tetrabenz-16-crown-8; tetrabenz-24-crown-8; tetrabenz-32-crown-8; tetrabenz-40-crown-8; tetrabenz-48-crown-8; octabenz-16-crown-8; octabenz-24-crown-8; octabenz-32-crown-8;

octabenzo-40-crown-8; and octabenzo-48-crown-8.

O Valence Stabilizer #17f: Examples of ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually ester or hydroxyl groups) and are not contained in component heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 20-crown-10; 30-crown-10; 40-crown-10; 50-crown-10; pentabenzo-20-crown-10; pentabenzo-30-crown-10; pentabenzo-40-crown-10; and pentabenzo-50-crown-10.

O Valence Stabilizer #18: Examples of four-, five-, six-, seven-, eight-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen and are contained in component 5-membered heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrafurans, tetrabenzofurans; pentafurans; pentabenzofurans; hexafurans; hexabenzofurans; heptafurans; heptabenzofurans; octafurans; octabenzofurans; decafurans; and decabenzofurans.

O Valence Stabilizer #19: Examples of four-, five-, six-, seven-, eight-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen and are contained in component 6-membered heterocyclic rings (O-O Bidentates, O-O Tridentates, O-O Tetracentates, and O-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetrapyrans, tetrabenzopyrans; pentapyrans; pentabenzopyrans; hexapyrans; hexabenzopyrans; heptapyrans; heptabenzopyrans; octapyrans; octabenzopyrans; decapyrans; and decabenzopyrans.

N-S Valence Stabilizer #1: Examples of thioimidates, dithioimidates, polythioimidates, and derivatives of thioimidic acid (N-S bidentates and N-S tetracentates) that meet the requirements

for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: S-methyl formathioimide; S-ethyl formathioimide; S-methyl acetathioimide; S-ethyl acetathioimide; S-methyl benzthioimide; S-ethyl benzthioimide; S-methyl cyclohexylthioimide; S-ethyl cyclohexylthioimide; S-methyl pentafluorobenzthioimide; S-ethyl pentafluorobenzthioimide; S-methyl 2-pyridylthioimide; S-ethyl 2-pyridylthioimide; S,S'-dimethyl benzdithioimide; S,S'-dimethyl tetrafluorobenzdithioimide; 2-iminothiolane; and 2-iminotetrahydrothiopyran. [Note: many thioimide complexes are decomposed by water, but their stability can be enhanced through the use of fluorinated solubility control anions (e.g., PF_6^-).]

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N-S Valence Stabilizer #2: Examples of thioguanylureas, guanidinothioureas, bis(thioguanylureas), bis(guanidinothioureas), poly(thioguanylureas), and poly(guanidinothioureas) (N-S Bidentates and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thioguanylurea (amidinothiourea); guanidinothiourea; methylthioguanylurea; ethylthioguanylurea; isopropylthioguanylurea; butylthioguanylurea; benzylthioguanylurea; phenylthioguanylurea; tolylthioguanylurea; naphthylthioguanylurea; cyclohexylthioguanylurea; norbornylthioguanylurea; adamantylthioguanylurea; dimethylthioguanylurea; diethylthioguanylurea; diisopropylthioguanylurea; dibutylthioguanylurea; dibenzylthioguanylurea; diphenylthioguanylurea; ditolylthioguanylurea; dinaphthylthioguanylurea; dicyclohexylthioguanylurea; dinorbornylthioguanylurea; diadamantylthioguanylurea; ethylenebis(thioguanylurea); propylenebis(thioguanylurea); phenylenebis(thioguanylurea); piperazinebis(thioguanylurea); oxalylbis(thioguanylurea); malonylbis(thioguanylurea); succinylbis(thioguanylurea); and phthalylbis(thioguanylurea). [Note: thioguanylureas generally tend to favor lower oxidation states in complexed metals.]

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N-S Valence Stabilizer #3: Examples of amidinothioamides, guanidinothioamides, bis(amidinothioamides), bis(guanidinothioamides), poly(amidinothioamides), and poly(guanidinothioamides) (including both N-amidinothioamides and 2-amidinothioacetamides) (N-S Bidentates, N-S Tridentates, and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: amidinothioacetamide;

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- guanidinothioamide, amidinothiopropylamide; amidinothiobutanamide; amidinothiobenzamide; amidinothiotoluamide; amidinothiocyclohexamide; N-methylamidinothioacetamide; N-ethylamidinothiopropylamide; N-propylamidinothiobutanamide; N-phenylamidinothiobenzamide; N-tolylamidinothiotoluamide; N-cyclohexylamidinothiocyclohexamide; bis(amidinothiooxamide); bis(amidinothiomalonamide); bis(amidinothiosuccinamide); bis(amidinothiophthalamide); 2-amidinothioacetamide (thiomalonamamide); N-methyl-2-amidinothioacetamide; N-ethyl-2-amidinothioacetamide; N-phenyl-2-amidinothioacetamide; N-benzyl-2-amidinothioacetamide; N-cyclohexyl-2-amidinothioacetamide; N,N'-dimethyl-2-amidinothioacetamide; N,N'-diethyl-2-amidinothioacetamide; N,N'-diphenyl-2-amidinothioacetamide; N,N'-dibenzyl-2-amidinothioacetamide; and N,N'-dicyclohexyl-2-amidinothioacetamide. [Note: amidinothioamides generally tend to favor lower oxidation states in complexed metals.]

- N-S Valence Stabilizer #4: Examples of imidothioamides, bis(imidothioamides), and poly(imidothioamides) (N-S Bidentates, N-S Tridentates, and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: acetimidoylthioacetamide; acetimidoylthiopropylamide; acetimidoylthiobutanamide; acetimidoylthiobenzamide; acetimidoylthiotoluamide; acetimidoylthiocyclohexamide; propimidoylthiopropylamide; butimidoylthiobutanamide; benzimidoylthiobenzamide; ethylenebis(acetimidoylthioacetamide); propylenebis(acetimidoylthioacetamide); and phenylenebis(acetimidoylthioacetamide). [Note: imidothioamides generally tend to favor lower oxidation states in complexed metals.]

- N-S Valence Stabilizer #5: Examples of thioureas, bis(thioureas), and poly(thioureas), including thiourylene complexes (N-S bidentates and N-S tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiourea; methylthiourea; ethylthiourea; isopropylthiourea; benzylthiourea; phenylthiourea; cyclohexylthiourea; naphthylthiourea (ntu); biphenylthiourea; norbornylthiourea; adamantylthiourea; N,N'-dimethylthiourea; N,N'-diethylthiourea; N,N'-diisopropylthiourea; N,N'-dibenzylthiourea; N,N'-dicyclohexylthiourea; N,N'-dinaphthylthiourea; N,N'-dibiphenylthiourea; N,N'-dinorbornylthiourea; N,N'-diadamantylthiourea; tetramethylthiourea;

ethylenethiourea (2-imidazolidinethione)(etu); 4,5-dihydroxy-2-imidazolinethione (dhetu); propylenethiourea; N-(thiazol-2-yl)thiourea; diphenylphosphinothiyl thioureas; allylthiourea; N-allyl-N'-pyridylthiourea; N-allyl-N'-anisylthiourea; N-allyl-N'-naphthylthiourea; N-allyl-N'-phenylthiourea; thioglycoluril (acetylenethiourea); and bis(pyridylmethyl)thiourea. [Note:

5 thioureas generally tend to favor lower oxidation states in complexed metals.]

N-S Valence Stabilizer #6: Examples of thiocarboxamides, bis(thiocarboxamides), and poly(thiocarboxamides), (N-S bidentates, N-S tridentates, and N-S tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

10 thiocarbamide (tu); thioacetamide (taa); thiopropionamide; thiobutanamide; thiobenzamide (1-phenylthioformamide)(tba); 1-naphthylthioformamide; 1-cyclohexylthioformamide); 1-norbornylthioformamide; 1-adamantylthioformamide; N,N-dimethylthioformamide; N,N-dimethylthioacetamide; pyridine-2-thiocarboxamide (thiopicolinamide); pyrazine-2,3-dithiocarboxamide; thionicotinamide; 2-thiophenethiocarboxamide; N,N-

15 dimethylthiobenzamide; N-ethylthiocarbamide (N-etu); tetramethylthiocarbamide (tmtu); 2-thioacetamidothiazole (tatz); and polythioacrylamides. [Note: thiocarboxamides generally tend to favor lower oxidation states in complexed metals.]

N-S Valence Stabilizer #7: Examples of imidosulfurous diamides and bis(imidosulfurous

20 diamides) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-diphenylimidosulfurous diamide; N,N'-dibenzylimidosulfurous diamide; and phenylenebis(imidosulfurous diamide). [Note: these complexes tend to hydrolyze unless stabilized with a fluorinated anionic solubility control agent. The sulfite (S^{+4}) valence of the

25 sulfur atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

N-S Valence Stabilizer #8: Examples of sulfurdiimines, bis(sulfurdiimines), and

poly(sulfurdiimines) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates) that meet the

30 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-diphenylsulfurdiimine; N,N'-dibenzylsulfurdiimine; and phenylenebis(sulfurdiimine).

[Note: these complexes tend to hydrolyze unless stabilized with a fluorinated anionic solubility control agent. The sulfite (S^{+4}) valence of the sulfur atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

- 5 N-S Valence Stabilizer #9: Examples of phosphonimidothioic acid, phosphonimidodithioic acid, bis(phosphonimidothioic acid); bis(phosphonimidodithioic acid), and derivatives thereof (N-S Bidentates, N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonimidothioic acid, phosphonimidodithioic acid; O-phenylphosphonimidothioic acid; O-benzylphosphonimidothioic acid; O-cyclohexylphosphonimidothioic acid; O-norbornylphosphonimidothioic acid; S-phenylphosphonimidodithioic acid; S-benzylphosphonimidodithioic acid; S-cyclohexylphosphonimidodithioic acid; and S-norbornylphosphonimidodithioic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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- N-S Valence Stabilizer #10: Examples of phosphonothioic diamides, bis(phosphonothioic diamides), and poly(phosphonothioic diamides) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonothioic diamide, phosphonothioic dihydrazide, phosphonamidothioic hydrazide, N-phenylphosphonothioic diamide, N-benzylphosphonothioic diamide, N-cyclohexylphosphonothioic diamide, and N-norbornylphosphonothioic diamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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- 25 N-S Valence Stabilizer #11: Examples of phosphonamidothioic acid, phosphonamidimidodithioic acid, bis(phosphonamidothioic acid), bis(phosphonamidimidodithioic acid), poly(phosphonamidothioic acid), and poly(phosphonamidimidodithioic acid), and derivatives thereof (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonamidothioic acid, phosphonamidimidodithioic acid, phosphonhydrazidodithioic acid, phosphonhydrazidothioic acid, S-

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phenylphosphonamidimidodithioic acid, S-benzylphosphonamidimidodithioic acid, S-cyclohexylphosphonamidimidodithioic acid, and S-norbornylphosphonamidimidodithioic acid.

[Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizaton of high valence metal ions much more difficult, though still possible.]

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N-S Valence Stabilizer #12: Examples of beta-aminothiones (N-substituted 3-amino-2-propenethioaldehydes), bis(beta-aminothiones), and poly(beta-aminothiones) (N-S Bidentates and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-methylamino-3-penten-2-thione; 4-ethylamino-3-penten-2-thione; 4-isopropylamino-3-penten-2-thione; 4-phenylamino-3-penten-2-thione; 4-naphthylamino-3-penten-2-thione; 4-cyclohexylamino-3-penten-2-thione; 4-norbornylamino-3-penten-2-thione; 4-hydroxyamino-3-penten-2-thione; 3-methylamino-1-phenyl-2-butenethioaldehyde; 3-ethylamino-1-phenyl-2-butenethioaldehyde; 3-isopropylamino-1-phenyl-2-butenethioaldehyde; 3-phenylamino-1-phenyl-2-butenethioaldehyde; 3-naphthylamino-1-phenyl-2-butenethioaldehyde; 3-cyclohexylamino-1-phenyl-2-butenethioaldehyde; 3-norbornylamino-1-phenyl-2-butenethioaldehyde; 3-hydroxyamino-1-phenyl-2-butenethioaldehyde; 3-phenylamino-1,3-diphenyl-2-propenethioaldehyde; 3-cyclohexylamino-1,3-dicyclohexyl-2-propenethioaldehyde; and 3-norbornylamino-1,3-dinorbornyl-2-propenethioaldehyde.

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N-S Valence Stabilizer #13: Examples of 3-aminothioacrylamides (3-amino-2-thiopropenamides), 3,3-diaminothioacrylamides, bis(3-aminothioacrylamides), bis(3,3-diaminothioacrylamides), poly(3-aminothioacrylamides), and poly(3,3-diaminothioacrylamides) (N-S Bidentates and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-methylaminothioacrylamide; 3-ethylaminothioacrylamide, 3-isopropylaminothioacrylamide, 3-phenylaminothioacrylamide; 3-naphthylaminothioacrylamide; 3-cyclohexylaminothioacrylamide; 3-norbornylaminothioacrylamide; 3-hydroxyaminothioacrylamide; N-methyl-3-methylaminothioacrylamide; N-ethyl-3-ethylaminothioacrylamide, N-isopropyl-3-isopropylaminothioacrylamide, N-phenyl-3-phenylaminothioacrylamide; N-naphthyl-3-naphthylaminothioacrylamide; N-cyclohexyl-3-cyclohexylaminothioacrylamide; N-norbornyl-3-

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norbornylaminothioacrylamide; 3-amino-3-methylaminothioacrylamide; 3-amino-3-ethylaminothioacrylamide, 3-amino-3-isopropylaminothioacrylamide, 3-amino-3-phenylaminothioacrylamide; 3-amino-3-naphthylaminothioacrylamide; 3-amino-3-cyclohexylaminothioacrylamide; 3-amino-3-norbornylaminothioacrylamide; and 3-amino-3-
5 hydroxyaminothioacrylamide.

N-S Valence Stabilizer #14: Examples of 3-aminothioacrylic acids (3-amino-2-thiopropenoic acids), 3-mercapto-3-aminothioacrylic acids, bis(3-aminothioacrylic acids), bis(3-mercapto-3-aminothioacrylic acids), poly(3-aminothioacrylic acids), and poly(3-mercapto-3-

10 aminothioacrylic acids), and derivatives thereof (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-aminothioacrylic acid; 3-mercapto-3-aminothioacrylic acid; 3-methylaminothioacrylic acid; 3-ethylaminothioacrylic acid; 3-isopropylaminothioacrylic acid; 3-phenylaminothioacrylic acid; 3-naphthylaminothioacrylic acid; 3-cyclohexylaminothioacrylic
15 acid; 3-norbornylaminothioacrylic acid; 3-hydroxyaminothioacrylic acid; methyl 3-methylaminothioacrylate; ethyl 3-ethylaminothioacrylate; isopropyl 3-isopropylaminothioacrylate; benzyl 3-phenylaminothioacrylate; naphthyl 3-naphthylaminothioacrylate; cyclohexyl 3-cyclohexylaminothioacrylate; and norbornyl 3-norbornylaminothioacrylate.

20 N-S Valence Stabilizer #15: Examples of N-thioacyl benzylidenimines, bis(N-thioacyl benzylidenimines), and poly(N-thioacyl benzylidenimines) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N-thioformyl benzylidenimine, N-thioacetyl benzylidenimine; N-
25 thiobenzoyl benzylidenimine; and N-pentafluorothiobenzoyl benzylidenimine.

N-S Valence Stabilizer #16: Examples of thiocarbonyl oximes, bis(thiocarbonyl oximes), and poly(thiocarbonyl oximes) (N-S Bidentates, N-S Tridentates, and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not
30 limited to: butane-3-thione-2-one monoxime); and diphenylethane-2-thione-1-one monoxime.

N-S Valence Stabilizer #17: Examples of mercapto oximes, bis(mercapto oximes), and poly(mercapto oximes) (including 2-sulfur heterocyclic oximes) (N-S Bidentates, N-S Tridentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 3-mercaptobutan-2-one oxime; 4-mercaptohexan-3-one oxime; (1,2-diphenyl-2-mercaptoethanone oxime); 1,2-di(trifluoromethyl)-2-mercaptoethanone oxime; 1,2-dicyclohexyl-2-mercaptoethanone oxime; 1,2-dinorbornyl-2-mercaptoethanone oxime; 2-mercaptobenzaldehyde oxime; 2-mercapto-1-naphthaldehyde oxime; thiophene-2-aldoxime; methyl 2-thiophenyl ketoxime; and phenyl 2-thiophenyl ketoxime.

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N-S Valence Stabilizer #18: Examples of 2-nitrothiophenols (2-nitrobenzenethiols) (N-S Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-nitrothiophenol; 2,3-dinitrothiophenol; 2,4-dinitrothiophenol; 2,5-dinitrothiophenol; 2,6-dinitrothiophenol; 1-nitro-2-naphthalenethiol; and 2-nitro-1-naphthalenethiol.

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N-S Valence Stabilizer #19: Examples of 2-nitrilothiophenols (2-nitrilobenzenethiols) (N-S Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-cyanothiophenol; 2,3-dicyanothiophenol; 2,4-dicyanothiophenol; 2,5-dicyanothiophenol; 2,6-dicyanothiophenol; 1-cyano-2-naphthalenethiol; and 2-cyano-1-naphthalenethiol.

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N-S Valence Stabilizer #20: Examples of thiohydrazides, bis(thiohydrazides), and poly(thiohydrazides) (N-S Bidentates and N-S Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thioformic hydrazide; thioacetic hydrazide; thiopropionic hydrazide; thiobenzoic hydrazide; thiophthalhydrazide; thiosalicylic hydrazide; thionaphthoic hydrazides; thionorbornaneacetic hydrazide; thionicotinic hydrazide; and thioisonicotinic hydrazide. [Note: thiohydrazides prefer complexation with lower oxidation states in metal ions.]

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N-S Valence Stabilizer #21: Examples of thiosemicarbazides, bis(thiosemicarbazides), and poly(thiosemicarbazides) (N-S Bidentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiosemicarbazide (tsc); thiosemicarbazide diacetic acid (tsda); 1-

- 5 methylthiosemicarbazide (1mts); 1-ethylthiosemicarbazide; 1-isopropylthiosemicarbazide; 1-phenylthiosemicarbazide (1pts)(cryogenine); 1-benzylthiosemicarbazide; 1-cyclohexylthiosemicarbazide; 1-norbornylthiosemicarbazide; 4-methylthiosemicarbazide (4mts); 4-ethylthiosemicarbazide; 4-isopropylthiosemicarbazide; 4-phenylthiosemicarbazide (4-pts); 4-benzylthiosemicarbazide; 4-cyclohexylthiosemicarbazide; 4-norbornylthiosemicarbazide;
- 10 nicotinic thiosemicarbazide; isonicotinic thiosemicarbazide; and 4-phenyl-1-benzenesulfonyl-3-thiosemicarbazide (pbst). [Note: thiosemicarbazides prefer complexation with lower oxidation states in metal ions.]

N-S Valence Stabilizer #22: Examples of five-, seven-, or nine-membered macrocyclics,

- 15 macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepolchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) or sulfur (usually thiols, mercaptans, or thiocarbonyls) and are not contained in component heterocyclic rings (N-S Tridentates, N-S Tetradentates, and N-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
- 20 triazadithiacyclodecane ([10]aneS₂N₃); triazadithiacycloundecane ([11]aneS₂N₃); triazadithiacyclododecane ([12]aneS₂N₃); triazadithiacyclotridecane ([13]aneS₂N₃); triazadithiacyclotetradecane ([14]aneS₂N₃); triazadithiacyclopentadecane ([15]aneS₂N₃); thiomorpholine; and thiazolidine.

25 N-S Valence Stabilizer #23: Examples of five- or seven-membered macrocyclics,

- macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepolchrates) wherein all binding sites are composed of nitrogen or sulfur and are contained in component heterocyclic rings (N-S Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4}
- 30 include, but are not limited to: dithiopyrantripyrindines; dithiophenetripyrroles; trithiopyrantetrapyrindines; and trithiophenetetrapyrroles.

N-S Valence Stabilizer #24: Examples of five-, seven-, or nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or sulfur and are contained in a combination of heterocyclic rings and amine, imine, thiol, mercapto, or thiocarbonyl groups (N-S
5 Bidentates, N-S Tridentates, N-S Tetradentates, or N-S Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: azathiapentaphyrins; diazadithiapentaphyrins; azathiapentaphyrins; and diazadithiapentaphyrins.

N-O Valence Stabilizer #1: Examples of imidates, diimidates, polyimidates, and derivatives of
10 imidic acid (N-O bidentates and N-O tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: O-methyl formimide; O-ethyl formimide; O-methyl acetimidate; O-ethyl acetimidate; O-methyl benzimidate; O-ethyl benzimidate; O-methyl cyclohexylimide; O-ethyl cyclohexylimide; O-methyl pentafluorobenzimidate; O-ethyl pentafluorobenzimidate; O-methyl 2-pyridylimide; O-ethyl 2-
15 pyridylimide; O,O'-dimethyl benzdiimide; O,O'-dimethyl tetrafluorobenzdiimide; 2-iminotetrahydrofuran; and 2-iminotetrahydropyran. [Note: most imide complexes are decomposed by water, but their stability can be enhanced through the use of fluorinated solubility control anions (e.g., PF_6^-).]

20 N-O Valence Stabilizer #2: Examples of pseudoureas, bis(pseudoureas), and poly(pseudoureas) (N-O bidentates and N-O tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: O-methyl pseudourea; O-ethyl pseudourea; O-isopropyl pseudourea; O-benzyl pseudourea; O-cyclohexyl pseudourea; O-norbornyl pseudourea; O-pentafluorobenzyl pseudourea; N-methyl pseudourea; N-ethyl
25 pseudourea; N-isopropyl pseudourea; N-benzyl pseudourea; N-cyclohexyl pseudourea; N-norbornyl pseudourea; and N-pentafluorobenzyl pseudourea.

N-O Valence Stabilizer #3: Examples of 2-amidinoacetates, bis(2-amidinoacetates), and poly(2-amidinoacetates) (N-O Bidentates and N-O Tetradentates) that meet the requirements for use as
30 “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N-methyl-2-amidinoacetate; O-methyl-2-amidinoacetate; N-benzyl-2-amidinoacetate; and O-benzyl-2-

amidinoacetate. [Note: many 2-amidinoacetates tend to hydrolyze in water. This can be minimized through the use of fluorinated solubility control anions such as PF_6^- .]

N-O Valence Stabilizer #4: Examples of ureas, bis(ureas), and poly(ureas), including urylene

5 complexes (N-O bidentates and N-O tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: urea; methylurea; ethylurea; isopropylurea; benzylurea; cyclohexylurea; naphthylurea; biphenylurea; norbornylurea; adamantylurea; N,N'-dimethylurea; N,N'-diethylurea; N,N'-diisopropylurea; N,N'-dibenzylurea; N,N'-dicyclohexylurea; N,N'-dinaphthylurea; N,N'-dibiphenylurea; N,N'-dinorbornylurea; N,N'-
10 diadamantylurea; ethyleneurea (2-imidazolidone); propyleneurea; glycoluril (acetyleneurea); and N,N'-bis(4-nitrophenyl)urea.

N-O Valence Stabilizer #5: Examples of phosphonimidic acid, bis(phosphonimidic acid),

poly(phosphonimidic acid), and derivatives thereof (N-O Bidentates and N-O Tetradentates) that
15 meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonimidic acid; O-phenylphosphonimidic acid; O-benzylphosphonimidic acid; O-cyclohexylphosphonimidic acid; and O-norbornylphosphonimidic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

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N-O Valence Stabilizer #6: Examples of phosphonamidic acid, phosphonic diamide,

bis(phosphonamidic acid), bis(phosphonic diamide), poly(phosphonamidic acid),
poly(phosphonic diamide), and derivatives thereof (N-O Bidentates and N-O Tetradentates) that
25 meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphonamidic acid, phosphonic diamide, phosphonamidic hydrazide, phosphonic dihydrazide, O-phenylphosphonamidic acid, O-benzylphosphonamidic acid, O-cyclohexylphosphonamidic acid, O-norbornylphosphonamidic acid, N-benzylphosphonic diamide, N-phenylphosphonic diamide, N-cyclohexylphosphonic diamide, and N-norbornylphosphonic diamide. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes
30 stabilizization of high valence metal ions much more difficult, though still possible.]

N-O Valence Stabilizer #7: Examples of beta-ketoamines (N-substituted 3-amino-2-propenals), bis(beta-ketoamines), and poly(beta-ketoamines) (N-O Bidentates and N-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not

limited to: 4-methylamino-3-penten-2-one; 4-ethylamino-3-penten-2-one; 4-isopropylamino-3-

5 penten-2-one; 4-phenylamino-3-penten-2-one; 4-naphthylamino-3-penten-2-one; 4-

cyclohexylamino-3-penten-2-one; 4-norbornylamino-3-penten-2-one; 4-hydroxyamino-3-penten-

2-one; 3-methylamino-1-phenyl-2-butenal; 3-ethylamino-1-phenyl-2-butenal; 3-isopropylamino-

1-phenyl-2-butenal; 3-phenylamino-1-phenyl-2-butenal; 3-naphthylamino-1-phenyl-2-butenal; 3-

cyclohexylamino-1-phenyl-2-butenal; 3-norbornylamino-1-phenyl-2-butenal; 3-hydroxyamino-

10 1-phenyl-2-butenal; 3-phenylamino-1,3-diphenyl-2-propenal; 3-cyclohexylamino-1,3-

dicyclohexyl-2-propenal; 3-norbornylamino-1,3-dinorbornyl-2-propenal; 2,2'-pyridil; alpha-

pyridoin; 4-aminoantipyrine (aap); beta-phenylaminopropiophenone; and polyaminoquinones

(PAQs).

15 N-O Valence Stabilizer #8: Examples of 3-aminoacrylamides (3-amino-2-propenamides), 3,3-

diaminoacrylamides, bis(3-aminoacrylamides), bis(3,3-diaminoacrylamides), poly(3-

aminoacrylamides), and poly(3,3-diaminoacrylamides) (N-O Bidentates and N-O Tetracentates)

that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are

not limited to: 3-methylaminoacrylamide; 3-ethylaminoacrylamide, 3-

20 isopropylaminoacrylamide, 3-phenylaminoacrylamide; 3-naphthylaminoacrylamide; 3-

cyclohexylaminoacrylamide; 3-norbornylaminoacrylamide; 3-hydroxyaminoacrylamide; N-

methyl-3-methylaminoacrylamide; N-ethyl-3-ethylaminoacrylamide, N-isopropyl-3-

isopropylaminoacrylamide, N-phenyl-3-phenylaminoacrylamide; N-naphthyl-3-

naphthylaminoacrylamide; N-cyclohexyl-3-cyclohexylaminoacrylamide; N-norbornyl-3-

25 norbornylaminoacrylamide; 3-amino-3-methylaminoacrylamide; 3-amino-3-

ethylaminoacrylamide, 3-amino-3-isopropylaminoacrylamide, 3-amino-3-

phenylaminoacrylamide; 3-amino-3-naphthylaminoacrylamide; 3-amino-3-

cyclohexylaminoacrylamide; 3-amino-3-norbornylaminoacrylamide; and 3-amino-3-

hydroxyaminoacrylamide.

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N-O Valence Stabilizer #9: Examples of 3-aminoacrylic acids (3-amino-2-propenoic acids), 3-hydroxy-3-aminoacrylic acids, bis(3-aminoacrylic acids), bis(3-hydroxy-3-aminoacrylic acids), poly(3-aminoacrylic acids), and poly(3-hydroxy-3-aminoacrylic acids), and derivatives thereof (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “narrow band”

- 5 valence stabilizers for Ce^{+4} include, but are not limited to: 3-aminoacrylic acid; 3-hydroxy-3-aminoacrylic acid; 3-methylaminoacrylic acid; 3-ethylaminoacrylic acid; 3-isopropylaminoacrylic acid; 3-phenylaminoacrylic acid; 3-naphthylaminoacrylic acid; 3-cyclohexylaminoacrylic acid; 3-norbornylaminoacrylic acid; 3-hydroxyaminoacrylic acid; methyl 3-methylaminoacrylate; ethyl 3-ethylaminoacrylate; isopropyl 3-isopropylaminoacrylate; 10 benzyl 3-phenylaminoacrylate; naphthyl 3-naphthylaminoacrylate; cyclohexyl 3-cyclohexylaminoacrylate; and norbornyl 3-norbornylaminoacrylate.

N-O Valence Stabilizer #10: Examples of N-acyl benzylidenimines, bis(N-acyl benzylidenimines), and poly(N-acyl benzylidenimines) (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N-formyl benzylidenimine, N-acetyl benzylidenimine; N-benzoyl benzylidenimine; and N-pentafluorobenzoyl benzylidenimine.

- N-O Valence Stabilizer #11: Examples of 2-nitroanilines (N-O Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 20 2-nitroaniline; 2,6-dinitroaniline; 2-nitrophenylenediamine; 2-nitrophenylenetriamine; 2-nitro-1-aminonaphthalene; 1-nitro-2-aminonaphthalene; nitrodiaminonaphthalene; and dipicrylamine.

- N-O Valence Stabilizer #12: Examples of 2-nitrophenols (N-O Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 25 2-cyanophenol; 2,3-dicyanophenol; 2,4-dicyanophenol; 2,5-dicyanophenol; 2,6-dicyanophenol; 1-cyano-2-naphthol; and 2-cyano-1-naphthol. Also includes acylcyanamides.

- N-O Valence Stabilizer #13: Examples of amine N-oxides and N-diazine oxides (azoxy compounds) (N-O Bidentates, N-O Tridentates, and N-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 30

pyridine N-oxide (pyNO or PNO); picoline N-oxide (picNO); lutidine N-oxide (lutNO or LNO); collidine N-oxide (collNO or CNO); quinoline N-oxide (QuinNO or QNO); isoquinoline N-oxide (isoQuinNO or IQNO); acridine N-oxide (AcrNO or ANO); picolinic acid N-oxide (PicANO); pyridinethiolate N-oxide (PTNO); adenine N-oxide; adenosine N-oxide; 1,10-phenanthroline mono-N-oxide (phenNO); 1,10-phenanthroline N,N-dioxide (phen2NO); bipyridyl mono-N-oxide (bipyNO); bipyridyl N,N-dioxide (bipy2NO); pyrazine mono-N-oxide (pyzNO); pyrazine N,N-dioxide (pyz2NO); pyrimidine mono-N-oxide (pymNO); pyrimidine N,N-dioxide (pym2NO); pyridazine mono-N-oxide (pdzNO); pyridazine N,N-dioxide (pdz2NO); quinoxaline mono-N-oxide (qxNO); quinoxaline N,N-dioxide (qx2NO); phenazine mono-N-oxide (phzNO); phenazine N,N-dioxide (phz2NO); 2,3-di(pyridine N-oxide)quinoxaline (dpq); inosine N-oxide; 4,4'-bipyridine N,N-dioxide; 1-hydroxypyrazole 2-oxide; 1-hydroxyimidazole 3-oxide; 2,2'-diimidazolyl 3,3'-dioxide; imidazole N-oxides (i.e., 1-hydroxyimidazole-3-N-oxides); N-benzylidene aniline N-oxide; N-(naphthylidene) aniline N-oxide; N-(hydroxybenzylidene) aniline N-oxide; and 2,2'-dibenzimidazolyl 3,3'-dioxide (indigo N,N-dioxide) for amine N-oxides; and azoxybenzene; phthalazine N-oxide; benzocinnoline N-oxide; and bipyrziny N-oxide as N-diazine oxide examples.

N-O Valence Stabilizer #14: Examples of hydrazides, bis(hydrazides), and poly(hydrazides) (N-O Bidentates and N-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: formic hydrazide; acetic hydrazide; propionic hydrazide; benzoic hydrazide; phthalhydrazide; salicylic hydrazide; naphthoic hydrazides; norbornaneacetic hydrazide; nicotinic hydrazide; and isonicotinic hydrazide (isoniazid). [Note: hydrazides prefer complexation with lower oxidation states in metal ions.]

N-O Valence Stabilizer #15: Examples of semicarbazides, bis(semicarbazides), and poly(semicarbazides) (N-O Bidentates, N-O Tetridentates, and N-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: semicarbazide (sc); semicarbazide diacetic acid (sda); 1-methylsemicarbazide; 1-ethylsemicarbazide; 1-isopropylsemicarbazide; 1-phenylsemicarbazide; 1-benzylsemicarbazide; 1-cyclohexylsemicarbazide; 1-norbornylsemicarbazide; 4-methylsemicarbazide; 4-ethylsemicarbazide; 4-isopropylsemicarbazide; 4-phenylsemicarbazide; 4-benzylsemicarbazide;

4-cyclohexylsemicarbazide; 4-norbornylsemicarbazide; nicotinic semicarbazide; and isonicotinic semicarbazide. [Note: semicarbazides prefer complexation with lower oxidation states in metal ions.]

- 5 N-O Valence Stabilizer #16: Examples of five-, seven-, or nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) or oxygen (usually hydroxy, carboxy, or carbonyl groups) and are not contained in component heterocyclic rings (N-O Tridentates, N-O Tetracentates, and N-O Hexacentates) that meet the
- 10 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: triazadioxacyclodecane ([10]aneO₂N₃); triazadioxacycloundecane ([11]aneO₂N₃); triazadioxacyclododecane ([12]aneO₂N₃); triazadioxacyclotridecane ([13]aneO₂N₃); triazadioxacyclotetradecane ([14]aneO₂N₃); and triazadioxacyclopentadecane ([15]aneO₂N₃).
- 15 N-O Valence Stabilizer #17: Examples of five- or seven-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or oxygen and are contained in component heterocyclic rings (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O
- 20 Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dipyrantripyridines; difurantripyrroles; tripyrantetrapyridines; and trifurantetrapyroles.

- N-O Valence Stabilizer #18: Examples of five-, seven-, or nine-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and
- 25 sepulchrates) wherein all binding sites are composed of nitrogen or oxygen and are contained in a combination of heterocyclic rings and amine, imine, hydroxy, carboxy, or carbonyl groups (N-O Bidentates, N-O Tridentates, N-O Tetracentates, or N-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: azaoxapentaphyrins; diazadioxapentaphyrins; azaoxapentaphyrins; and diazadioxapentaphyrins.

S-O Valence Stabilizer #1: Examples of thiobiurets (thioimidodicarbonic diamides), thioisobiurets, thiobiureas, thiotriurets, thiotriureas, bis(thiobiurets), bis(thioisobiurets), bis(thiobiureas), poly(thiobiurets), poly(thioisobiurets), and poly(thiobiureas) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiobiuret, thioisobiuret, thiobiurea, thiotriuret, thiotriurea, nitrothiobiuret, dinitrothiobiuret, aminothiobiuret, diaminothiobiuret, oxythiobiuret, dioxythiobiuret, cyanothiobiuret, methylthiobiuret, ethylthiobiuret, isopropylthiobiuret, phenylthiobiuret, benzylthiobiuret, cyclohexylthiobiuret, norbornylthiobiuret, adamantylthiobiuret, dimethylthiobiuret, diethylthiobiuret, diisopropylthiobiuret, diphenylthiobiuret, dibenzylthiobiuret, dicyclohexylthiobiuret, dinorbornylthiobiuret, diadamantylthiobiuret; and (3-formamidino thiocarbamides).

S-O Valence Stabilizer #2: Examples of acylthioureas, aroylthioureas, thioacylureas, thioaroylureas, bis(acylthioureas), bis(aroylthioureas), bis(thioacylureas), bis(thioaroylureas), poly(thioacylthioureas), poly(thioaroylthioureas), poly(thioacylureas), and poly(thioaroylureas) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thioformylurea, thioacetylurea, thiobenzoylurea, thiocyclohexoylurea, pentafluorothiobenzoylurea, acetylthiourea, benzoylthiourea, and cyclohexoylthiourea.

S-O Valence Stabilizer #3: Examples of thioimidodialdehydes, thiohydrazidodialdehydes (thioacyl hydrazides), bis(thioimidodialdehydes), bis(thiohydrazidodialdehydes), poly(thioimidodialdehydes), and poly(thiohydrazidodialdehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiodiacetamide, thiodipropanamide, thiodibutanamide, thiodibenzamide, and thiodicyclohexamide.

S-O Valence Stabilizer #4: Examples of thioimidodicarbonic acids, thiohydrazidodicarbonic acids, bis(thioimidodicarbonic acids), bis(thiohydrazidodicarbonic acids), poly(thioimidodicarbonic acids), poly(thiohydrazidodicarbonic acids) and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow

band” valence stabilizers for Ce^{+4} include, but are not limited to: thioimidodicarbonic acid, thiohydrazidodicarbonic acid, O-phenylthioimidodicarbonic acid, O-benzylthioimidodicarbonic acid, O-cyclohexylthioimidodicarbonic acid, O-norbornylthioimidodicarbonic acid, O,O'-diphenylthioimidodicarbonic acid, O,O'-dibenzylthioimidodicarbonic acid, O,O'-dicyclohexylthioimidodicarbonic acid, O,O'-dinorbornylthioimidodicarbonic acid.

S-O Valence Stabilizer #5: Examples of 1,2-monothioketones (monothioenes, monothio-alpha-ketonates), 1,2,3-monothioketones, 1,2,3-dithioketones, monothiotropolonates, ortho-monothioquinones, bis(1,2-monothioketones), and poly(1,2-monothioketones) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiotropolone; 1,2-monothiobenzoquinone (o-monothioquinone); di-tert-butyl-1,2-monothiobenzoquinone; hexafluoro-1,2-monothiobenzoquinone; 1,2-monothionaphthoquinone; 9,10-monothiophenanthroquinone; monothiosquaric acid; monothiodeltic acid; monothiocroconic acid; and monothiorhodizonic acid.

S-O Valence Stabilizer #6: Examples of trithioperoxydicarbonic diamides, bis(trithioperoxydicarbonic diamides), and poly(trithioperoxydicarbonic diamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: trithioperoxydicarbonic diamide; N-phenyltrithioperoxydicarbonic diamide; N-benzyltrithioperoxydicarbonic diamide; N-cyclohexyltrithioperoxydicarbonic diamide; N-norbornyltrithioperoxydicarbonic diamide; N,N'-diphenyltrithioperoxydicarbonic diamide; N,N'-dibenzyltrithioperoxydicarbonic diamide; N,N'-dicyclohexyltrithioperoxydicarbonic diamide; and N,N'-dinorbornyltrithioperoxydicarbonic diamide.

S-O Valence Stabilizer #7: Examples of dithiodicarbonic acids, bis(dithiodicarbonic acids), poly(dithiodicarbonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodicarbonic acid, O-phenyldithiodicarbonic acid, O-benzylthiodithiodicarbonic acid, O-cyclohexyldithiodicarbonic acid, O-norbornyldithiodicarbonic

acid, O,O'-diphenyldithiodicarbonic acid, O,O'-dibenzylthiodicarbonic acid, O,O'-dicyclohexyldithiodicarbonic acid, and O,O'-dinorbornyldithiodicarbonic acid.

S-O Valence Stabilizer #8: Examples of trithioperoxydicarbonic acids,

- 5 bis(trithioperoxydicarbonic acids), poly(trithioperoxydicarbonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
- trithioperoxydicarbonic acid, O-phenyltrithioperoxydicarbonic acid; O-benzyltrithioperoxydicarbonic acid; O-cyclohexyltrithioperoxydicarbonic acid; O-
- 10 norbornyltrithioperoxydicarbonic acid; O,O'-diphenyltrithioperoxydicarbonic acid; O,O'-dibenzyltrithioperoxydicarbonic acid; O,O'-dicyclohexyltrithioperoxydicarbonic acid; and O,O'-dinorbornyltrithioperoxydicarbonic acid.

S-O Valence Stabilizer #9: Examples of monothioperoxydiphosphoramides,

- 15 bis(monothioperoxydiphosphoramides), and poly(monothioperoxydiphosphoramides) (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
- monothioperoxydiphosphoramide, N-methylmonothioperoxydiphosphoramide, N-isopropylmonothioperoxydiphosphoramide, N-tert-butylmonothioperoxydiphosphoramide, N-
- 20 phenylmonothioperoxydiphosphoramide, N-pentafluorophenylmonothioperoxydiphosphoramide, N-benzylmonothioperoxydiphosphoramide, N-cyclohexylmonothioperoxydiphosphoramide, N-norbornylmonothioperoxydiphosphoramide, N,N''-dimethylmonothioperoxydiphosphoramide, N,N''-diisopropylmonothioperoxydiphosphoramide, N,N''-di-tert-
- butylmonothioperoxydiphosphoramide, N,N''-diphenylmonothioperoxydiphosphoramide,
- 25 N,N''-di-pentafluorophenylmonothioperoxydiphosphoramide, N,N''-dibenzylmonothioperoxydiphosphoramide, N,N''-dicyclohexylmonothioperoxydiphosphoramide, and N,N''-dinorbornylmonothioperoxydiphosphoramide.

- 30 S-O Valence Stabilizer #10: Examples of monothioperoxydiphosphoric acids, bis(monothioperoxydiphosphoric acids), poly(monothioperoxydiphosphoric acids), and

derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

monothiooxydiphosphoric acid, methylmonothiooxydiphosphoric acid, isopropylmonothiooxydiphosphoric acid, tert-butylmonothiooxydiphosphoric acid, 5 phenylmonothiooxydiphosphoric acid, pentafluorophenylmonothiooxydiphosphoric acid, benzylmonothiooxydiphosphoric acid, cyclohexylmonothiooxydiphosphoric acid, norbornylmonothiooxydiphosphoric acid, dimethylmonothiooxydiphosphoric acid, diisopropylmonothiooxydiphosphoric acid, di-tert-butylmonothiooxydiphosphoric acid, diphenylmonothiooxydiphosphoric acid, di-pentafluorophenylmonothiooxydiphosphoric 10 acid, dibenzylmonothiooxydiphosphoric acid, dicyclohexylmonothiooxydiphosphoric acid, and dinorbornylmonothiooxydiphosphoric acid.

S-O Valence Stabilizer #11: Examples of monothioimidodiphosphonic acids,

monothiohydrazidodiphosphonic acids, bis(monothioimidodiphosphonic acids),

15 bis(monothiohydrazidodiphosphonic acids), poly(monothioimidodiphosphonic acids), poly(monothiohydrazidodiphosphonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioimidodiphosphonic acid, methylmonothioimidodiphosphonic acid, isopropylmonothioimidodiphosphonic acid, tert- 20 butylmonothioimidodiphosphonic acid, phenylmonothioimidodiphosphonic acid, pentafluorophenylmonothioimidodiphosphonic acid, benzylmonothioimidodiphosphonic acid, cyclohexylmonothioimidodiphosphonic acid, norbornylmonothioimidodiphosphonic acid, dimethylmonothioimidodiphosphonic acid, diisopropylmonothioimidodiphosphonic acid, di-tert-butylmonothioimidodiphosphonic acid, diphenylmonothioimidodiphosphonic acid, di- 25 pentafluorophenylmonothioimidodiphosphonic acid, dibenzylmonothioimidodiphosphonic acid, dicyclohexylmonothioimidodiphosphonic acid, and dinorbornylmonothioimidodiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilization of high valence metal ions much more difficult, though still possible.]

30 S-O Valence Stabilizer #12: Examples of monothioimidodiphosphonamides,

monothiohydrazidodiphosphonamides, bis(monothioimidodiphosphonamides),

bis(monothiohydrazidodiphosphonamides), poly(monothioimidodiphosphonamides), and poly(monothiohydrazidodiphosphonamides) (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioimidodiphosphonamide, N-

- 5 methylmonothioimidodiphosphonamide, N-isopropylmonothioimidodiphosphonamide, N-tert-butylmonothioimidodiphosphonamide, N-phenylmonothioimidodiphosphonamide, N-pentafluorophenylmonothioimidodiphosphonamide, N-benzylmonothioimidodiphosphonamide, N-cyclohexylmonothioimidodiphosphonamide, N-norbornylmonothioimidodiphosphonamide, N,N'''-dimethylmonothioimidodiphosphonamide, N,N'''-
- 10 diisopropylmonothioimidodiphosphonamide, N,N'''-di-tert-butylmonothioimidodiphosphonamide, N,N'''-diphenylmonothioimidodiphosphonamide, N,N'''-di-pentafluorophenylmonothioimidodiphosphonamide, N,N'''-dibenzylmonothioimidodiphosphonamide, N,N'''-dicyclohexylmonothioimidodiphosphonamide, and N,N'''-dinorbornylmonothioimidodiphosphonamide. [Note: the phosphite (P^{+3}) valence of
- 15 the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #13: Examples of dithiodiphosphonamides,

- bis(dithiodiphosphonamides), and poly(dithiodiphosphonamides) (S-O Bidentates, S-O
- 20 Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodiphosphonamide, N-methyldithiodiphosphonamide, N-isopropyldithiodiphosphonamide, N-tert-butyldithiodiphosphonamide, N-phenyldithiodiphosphonamide, N-pentafluorophenyldithiodiphosphonamide, N-benzyl dithiodiphosphonamide, N-
- 25 cyclohexyldithiodiphosphonamide, N-norbornyldithiodiphosphonamide, N,N'''-dimethyldithiodiphosphonamide, N,N'''-diisopropyldithiodiphosphonamide, N,N'''-di-tert-butyldithiodiphosphonamide, N,N'''-diphenyldithiodiphosphonamide, N,N'''-di-pentafluorophenyldithiodiphosphonamide, N,N'''-dibenzyl dithiodiphosphonamide, N,N'''-dicyclohexyldithiodiphosphonamide, and N,N'''-dinorbornyldithiodiphosphonamide. [Note: the
- 30 phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #14: Examples of dithiodiphosphonic acids, bis(dithiodiphosphonic acids), poly(dithiodiphosphonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiodiphosphonic acid, methyldithiodiphosphonic acid, isopropyldithiodiphosphonic acid, tert-butyldithiodiphosphonic acid, phenyldithiodiphosphonic acid, pentafluorophenyldithiodiphosphonic acid, benzyldithiodiphosphonic acid, cyclohexyldithiodiphosphonic acid, norbornyldithiodiphosphonic acid, dimethyldithiodiphosphonic acid, diisopropyldithiodiphosphonic acid, di-tert-butyldithiodiphosphonic acid, diphenyldithiodiphosphonic acid, di-pentafluorophenyldithiodiphosphonic acid, dibenzyldithiodiphosphonic acid, dicyclohexyldithiodiphosphonic acid, and dinorbornyldithiodiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #15: Examples of monothioperoxydiphosponamides, bis(monothioperoxydiphosponamides), and poly(monothioperoxydiphosponamides) (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioperoxydiphosponamide, N-methylmonothioperoxydiphosponamide, N-isopropylmonothioperoxydiphosponamide, N-tert-butyldithiodiphosphonic acid, N-phenylmonothioperoxydiphosponamide, N-pentafluorophenylmonothioperoxydiphosponamide, N-benzylmonothioperoxydiphosponamide, N-cyclohexylmonothioperoxydiphosponamide, N-norbornylmonothioperoxydiphosponamide, N,N'-dimethylmonothioperoxydiphosponamide, N,N'-diisopropylmonothioperoxydiphosponamide, N,N'-di-tert-butyldithiodiphosphonic acid, N,N'-diphenylmonothioperoxydiphosponamide, N,N'-di-pentafluorophenylmonothioperoxydiphosponamide, N,N'-dibenzylmonothioperoxydiphosponamide, N,N'-dicyclohexylmonothioperoxydiphosponamide, and N,N'-dinorbornylmonothioperoxydiphosponamide. [Note: the phosphite (P^{+3}) valence of the

phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #16: Examples of monothiooxydiphosphonic acids,

- 5 bis(monothiooxydiphosphonic acids), poly(monothiooxydiphosphonic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiooxydiphosphonic acid, methylmonothiooxydiphosphonic acid, isopropylmonothiooxydiphosphonic acid, tert-butylmonothiooxydiphosphonic acid,
- 10 phenylmonothiooxydiphosphonic acid, pentafluorophenylmonothiooxydiphosphonic acid, benzylmonothiooxydiphosphonic acid, cyclohexylmonothiooxydiphosphonic acid, norbornylmonothiooxydiphosphonic acid, dimethylmonothiooxydiphosphonic acid, diisopropylmonothiooxydiphosphonic acid, di-tert-butylmonothiooxydiphosphonic acid, diphenylmonothiooxydiphosphonic acid, di-pentafluorophenylmonothiooxydiphosphonic
- 15 acid, dibenzylmonothiooxydiphosphonic acid, dicyclohexylmonothiooxydiphosphonic acid, and dinorbornylmonothiooxydiphosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

- 20 S-O Valence Stabilizer #17: Examples of monothioosphoric acids (phosphorothioic acids), bis(monothioosphoric acids), poly(monothioosphoric acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioosphoric acid, O-phenylmonothioosphoric acid, O-benzylmonothioosphoric acid, O-
- 25 cyclohexylmonothioosphoric acid, O-norbornylmonothioosphoric acid, O,O-diphenylmonothioosphoric acid, O,O-dibenzylmonothioosphoric acid, O,O-dicyclohexylmonothioosphoric acid, and O,O-dinorbornylmonothioosphoric acid.

S-O Valence Stabilizer #18: Examples of phosphoro(dithiooxyoic) acids,

- 30 bis[phosphoro(dithiooxyoic) acids], poly[phosphoro(dithiooxyoic) acids], and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use

as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

phosphoro(dithioperoxoic) acid, O-phenylphosphoro(dithioperoxoic) acid, O-benzylphosphoro(dithioperoxoic) acid, O-cyclohexylphosphoro(dithioperoxoic) acid, O-norbornylphosphoro(dithioperoxoic) acid, O,O-diphenylphosphoro(dithioperoxoic) acid, O,O-dibenzylphosphoro(dithioperoxoic) acid, O,O-dicyclohexylphosphoro(dithioperoxoic) acid, and O,O-dinorbornylphosphoro(dithioperoxoic) acid.

S-O Valence Stabilizer #19: Examples of monothiophosphonic Acids (phosphonothioic acids), bis(monothiophosphonic acids), poly(monothiophosphonic acids), and derivatives thereof (S-O

Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiophosphonic acid, O-phenylmonothiophosphonic acid, O-benzylmonothiophosphonic acid, O-cyclohexylmonothiophosphonic acid, O-norbornylmonothiophosphonic acid, O,P-diphenylmonothiophosphonic acid, O,P-dibenzylmonothiophosphonic acid, O,P-dicyclohexylmonothiophosphonic acid, and O,P-dinorbornylmonothiophosphonic acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #20: Examples of phosphono(dithioperoxoic) acids,

bis[phosphono(dithioperoxoic) acids], poly[phosphono(dithioperoxoic) acids], and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphono(dithioperoxoic) acid, O-phenylphosphono(dithioperoxoic) acid, O-benzylphosphono(dithioperoxoic) acid, O-cyclohexylphosphono(dithioperoxoic) acid, O-norbornylphosphono(dithioperoxoic) acid, O,P-diphenylphosphono(dithioperoxoic) acid, O,P-dibenzylphosphono(dithioperoxoic) acid, O,P-dicyclohexylphosphono(dithioperoxoic) acid, and O,P-dinorbornylphosphono(dithioperoxoic) acid. [Note: the phosphite (P^{+3}) valence of the phosphorus atom makes stabilizization of high valence metal ions much more difficult, though still possible.]

S-O Valence Stabilizer #21: Examples of beta-hydroxythioketones, beta-hydroxythioaldehydes, bis(beta-hydroxythioketones), bis(beta-hydroxythioaldehydes), poly(beta-hydroxythioketones), and poly(beta-hydroxythioaldehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-hydroxypentan-2-thione; 1,3-diphenyl-3-hydroxypropanethioaldehyde; 1,3-dibenzyl-3-hydroxypropanethioaldehyde; 1,3-dicyclohexyl-3-hydroxypropanethioaldehyde; 1,3-dinorbornyl-3-hydroxypropanethioaldehyde; 1,3-di(2-thienyl)-3-hydroxypropanethioaldehyde; 1,3-di(2-furyl)-3-hydroxypropanethioaldehyde; o-hydroxythioacetophenone; and beta-hydroxythiobenzophenone.

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S-O Valence Stabilizer #22: Examples of beta-mercaptoketones, beta-mercaptoaldehydes, bis(beta-mercaptoketones), bis(beta-mercaptoaldehydes), poly(beta-mercaptoketones), and poly(beta-mercaptoaldehydes) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-mercaptopentan-2-one; 1,3-diphenyl-3-mercaptopropanal; 1,3-dibenzyl-3-mercaptopropanal; 1,3-dicyclohexyl-3-mercaptopropanal; 1,3-dinorbornyl-3-mercaptopropanal; 1,3-di(2-thienyl)-3-mercaptopropanal; 1,3-di(2-furyl)-3-mercaptopropanal; 3-mercapto-1,5-pentanedialdehyde; o-mercaptoacetophenone; 5-mercapto-1,4-naphthoquinone; 1-mercaptoacridone; 1-mercaptoanthraquinone; 1,8-dimercaptoanthraquinone; and beta-mercaptobenzophenone.

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S-O Valence Stabilizer #23: Examples of N-(aminomethylol)thioureas [N-(aminohydroxymethyl)thioureas], bis[N-(aminomethylol)thioureas], and poly[N-(aminomethylol)thioureas] (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N’-(aminohydroxymethyl)thiourea; N,N’-dimethyl-N’-(aminohydroxymethyl)thiourea; N,N’-diethyl-N’-(aminohydroxymethyl)thiourea; N,N’-isopropyl-N’-(aminohydroxymethyl)thiourea; N,N’-diphenyl-N’-(aminohydroxymethyl)thiourea; N,N’-dibenzyl-N’-(aminohydroxymethyl)thiourea; N,N’-dicyclohexyl-N’-(aminohydroxymethyl)thiourea; and N,N’-dinorbornyl-N’-(aminohydroxymethyl)thiourea.

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S-O Valence Stabilizer #24: Examples of N-(aminomethylthiol)ureas [N-(aminomercaptomethyl)ureas], bis[N-(aminomethylthiol)ureas], and poly[N-(aminomethylthiol)ureas] (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 5 N’-(aminomercaptomethyl)urea; N,N’-dimethyl-N’-(aminomercaptomethyl)urea; N,N’-diethyl-N’-(aminomercaptomethyl)urea; N,N’-isopropyl-N’-(aminomercaptomethyl)urea; N,N’-diphenyl-N’-(aminomercaptomethyl)urea; N,N’-dibenzyl-N’-(aminomercaptomethyl)urea; N,N’-dicyclohexyl-N’-(aminomercaptomethyl)urea; and N,N’-dinorbornyl-N’-(aminomercaptomethyl)urea.

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S-O Valence Stabilizer #25: Examples of monothiooxamides, bis(monothiooxamides), and poly(monothiooxamides) (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothiooxamide, N-methylthiooxamide; N-ethylthiooxamide; N-isopropylthiooxamide; N-phenylthiooxamide; N-benzylthiooxamide; N-cyclohexylthiooxamide; N-norbornylthiooxamide; N,N’-dimethylthiooxamide; N,N’-diethylthiooxamide; N,N’-diisopropylthiooxamide; N,N’-diphenylthiooxamide; N,N’-dibenzylthiooxamide; N,N’-dicyclohexylthiooxamide; and N,N’-dinorbornylthiooxamide.

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- 20 S-O Valence Stabilizer #26: Examples of beta-mercapto carboxylic acids, bis(beta-mercapto carboxylic acids), poly(beta-mercapto carboxylic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl 3-mercaptopropanoate; methyl 3-mercaptoputanoate; ethyl 3-mercaptoputanoate; phenyl 3-mercaptoputanoate; cyclohexyl 3-mercaptoputanoate; norbornyl 3-mercaptoputanoate; methyl beta-mercaptophydrocinnamate; ethyl beta-mercaptophydrocinnamate; phenyl beta-mercaptophydrocinnamate; methyl o-mercaptopbenzoate; ethyl o-mercaptopbenzoate; phenyl o-mercaptopbenzoate; cyclohexyl o-mercaptopbenzoate; (2-benzothiazolylthio) succinic acid (mtbs); norbornyl o-mercaptopbenzoate; and 3-[(benzothiazol-2-yl)thio]propionic acid.

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S-O Valence Stabilizer #27: Examples of beta-mercapto thiocarboxylic acids, bis(beta-mercapto thiocarboxylic acids), poly(beta-mercapto thiocarboxylic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl 3-

- 5 mercaptothiobutanoate; ethyl 3-mercaptothiobutanoate; phenyl 3-mercaptothiobutanoate; cyclohexyl 3-mercaptothiobutanoate; norbornyl 3-mercaptothiobutanoate; methyl beta-mercaptothiocinnamate; ethyl beta-mercaptothiocinnamate; phenyl beta-mercaptothiocinnamate; methyl o-mercaptothiobenzoate; ethyl o-mercaptothiobenzoate; phenyl o-mercaptothiobenzoate; cyclohexyl o-mercaptothiobenzoate; norbornyl o-mercaptothiobenzoate; and (alkylthio)oxoethyl
10 alkyl(aryl) disulfides

S-O Valence Stabilizer #28: Examples of beta-hydroxy thiocarboxylic acids, bis(beta-hydroxy thiocarboxylic acids), poly(beta-hydroxy thiocarboxylic acids), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow

- 15 band” valence stabilizers for Ce^{+4} include, but are not limited to: methyl 3-hydroxythiobutanoate; ethyl 3-hydroxythiobutanoate; phenyl 3-hydroxythiobutanoate; cyclohexyl 3-hydroxythiobutanoate; norbornyl 3-hydroxythiobutanoate; methyl beta-hydroxythiocinnamate; ethyl beta-hydroxythiocinnamate; phenyl beta-hydroxythiocinnamate; methyl o-hydroxythiobenzoate; ethyl o-hydroxythiobenzoate; phenyl o-hydroxythiobenzoate; cyclohexyl o-hydroxythiobenzoate; and norbornyl o-hydroxythiobenzoate.
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S-O Valence Stabilizer #29: Examples of beta-mercapto carboxamides, bis(beta-mercapto carboxamides), poly(beta-mercapto carboxamides), and derivatives thereof (S-O Bidentates, S-O Tridentates, S-O Tetracentates) that meet the requirements for use as “narrow band” valence

- 25 stabilizers for Ce^{+4} include, but are not limited to: N-methyl 3-mercaptobutanamide; N-ethyl 3-mercaptobutanamide; N-phenyl 3-mercaptobutanamide; N-cyclohexyl 3-mercaptobutanamide; N-norbornyl 3-mercaptobutanamide; N-methyl o-mercaptobenzamide; N-ethyl o-mercaptobenzamide; N-phenyl o-mercaptobenzamide; N-cyclohexyl o-mercaptobenzamide; and N-norbornyl o-mercaptobenzamide.
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S-O Valence Stabilizer #30: Examples of S-alkylthiocarboxylic Acids, S-arylthiocarboxylic Acids, and S,S-thiobiscarboxylic Acids (S-O Bidentates and S-O Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: (methylthio)acetic acid; (methylthio)benzoic acid; (methylthio)nicotinic acid;

- 5 (methylthio)naphthoic acid; (phenylthio)acetic acid; (phenylthio)benzoic acid; (phenylthio)naphthoic acid; (norbornylthio)acetic acid; (norbornylthio)benzoic acid; (norbornylthio)naphthoic acid; thiobisacetic acid; thiobisbenzoic acid; and thiobisnaphthoic acid.

S-O Valence Stabilizer #31: Examples of S-alkyldisulfidocarboxylic acids, S-

- 10 aryldisulfidocarboxylic acids, and S,S'-disulfidobiscarboxylic acids (S-O Bidentates and S-O Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: (methyldisulfido)acetic acid; (methyldisulfido)benzoic acid; (methyldisulfido)nicotinic acid; (methyldisulfido)naphthoic acid; (phenyldisulfido)acetic acid; (phenyldisulfido)benzoic acid; (phenyldisulfido)naphthoic acid; (norbornyldisulfido)acetic acid;
- 15 (norbornyldisulfido)benzoic acid; (norbornyldisulfido)naphthoic acid; S,S'-disulfidobisacetic acid; S,S'-disulfidobisbenzoic acid; and S,S'-disulfidobisnaphthoic acid.

S-O Valence Stabilizer #32: Examples of monothiomonocarboxylic acids, dithiodicarboxylic acids, bis(monothiomonocarboxylic acids), bis(dithiodicarboxylic acids),

- 20 poly(monothiomonocarboxylic acids), poly(dithiodicarboxylic acids), and derivatives thereof (S-O Bidentates and S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thioacetic acid; thiopropionic acid; thiobenzoic acid; thiophenylacetic acid; thiocyclohexanoic acid; thiofuroic acid; thionaphthoic acid; phenyl thioacetate; phenyl thiopropionate; phenyl thiobenzoate; phenyl thiocyclohexanoate;
- 25 phenyl thiofuroate; phenyl thionaphthoate; dithiooxalic acid (dto); monothiooxalic acid (mtox); dithiomalonic acid; dithiosuccinic acid; diphenyl dithiooxalate; diphenyl dithiomalonate; and diphenyl dithiosuccinate.

S-O Valence Stabilizer #33: Examples of monothiocarbonates and bis(monothiocarbonates) (S-O

- 30 Bidentates and S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: S,O-diethyldithiocarbonate; S,O-

diisopropyldithiocarbonate; S,O-dipenyldithiocarbonate; S,O-dibenzoyldithiocarbonate; S,O-dicyclohexyldithiocarbonate; and S,O-dinorbornyldithiocarbonate.

S-O Valence Stabilizer #34: Examples of monothiocarbazates (monothiocarbazides),

- 5 bis(monothiocarbazates), and poly(monothiocarbazates) (S-O Bidentates, S-O Tridentates, and S-O Tetridentates; or possibly N-S Bidentates, N-S Tridentates, and N-S Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: N,N'-dimethylmonothiocarbazate; N,N'-di(trifluoromethyl)monothiocarbazate; N,N'-diethylmonothiocarbazate; N,N'-diphenylmonothiocarbazate; N,N'-dibenzylmonothiocarbazate;
- 10 N,N'-di(pentafluorophenyl)monothiocarbazate; N,N'-dicyclohexylmonothiocarbazate; and N,N'-dinorbornylmonothiocarbazate.

S-O Valence Stabilizer #35: Examples of mercapto alcohols and silylmercaptoalcohols,

- bis(mercapto alcohols and silylmercaptoalcohols), and poly(mercapto alcohols and
- 15 silylmercaptoalcohols) (S-O Bidentates, S-O Tridentates, S-O Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercaptoethanol (mel); 3-mercaptopropanol (mpl); 2-mercaptophenol; 2-mercaptocyclohexanol; 3-mercapto-2-norborneol; 2-mercaptopyridine 1-oxide; 1,4-thioxane; thiodialkanols; 2-(trimethoxysilyl)-1-ethanethiol (tmset); 3-(trimethoxysilyl)-1-propanethiol
- 20 (tmspt); o-hydroxythiophenols; o-(O-hydroxyalkyl(aryl))thiophenols; and o-(S-thioalkyl(aryl))phenols.

S-O Valence Stabilizer #36: Examples of monothiocarbimates, bis(monothiocarbimates), and

- poly(monothiocarbimates) (S-O Bidentates, S-O Tridentates, and S-O Tetridentates) that meet
- 25 the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: methylmonothiocarbimate; trifluoromethylmonothiocarbimate; ethylmonothiocarbimate; propylmonothiocarbimate; isopropylmonothiocarbimate; butylmonothiocarbimate; tertbutylmonothiocarbimate; cyanomonothiocarbimate; cyanamidomonothiocarbimate; azidomonothiocarbimate; phenylmonothiocarbimate;
- 30 pentafluorophenylmonothiocarbimate; benzylmonothiocarbimate; naphthylmonothiocarbimate;

cyclohexylmonothiocarbimate; norbornylmonothiocarbimate; and adamantylmonothiocarbimate.
[Note: carbimates tend to stabilize lower oxidation states in metal ions.]

S-O Valence Stabilizer #37: Examples of alkyl- and aryl- monothioborates and

- 5 bis(monothioborates) (S-O Bidentates and S-O Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: O,O’-diethyl monothioborate; O,O’-diisopropyl monothioborate; O,O’-diphenyl monothioborate; O,O’-dibenzyl monothioborate; O,O’-dicyclohexyl monothioborate; and O,O’-dinorbornyl monothioborate.

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S-O Valence Stabilizer #38: Examples of alkyl- and aryl- monothioboronates and

- bis(monothioboronates) (S-O Bidentates and S-O Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diethyl monothioboronate; diisopropyl monothioboronate; diphenyl monothioboronate; dibenzyl
15 monothioboronate; dicyclohexyl monothioboronate; and dinorbornyl monothioboronate. [Note: boronates tend to stabilize lower oxidation states in metal ions.]

S-O Valence Stabilizer #39: Examples of monothioarsonic acids (arsonothioic acids), bis(monothioarsonic acids), poly(monothioarsonic acids), and derivatives thereof (S-O

- 20 Bidentates, S-O Tridentates, S-O Tetradentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: monothioarsonic acid, O-phenylmonothioarsonic acid, O-benzylmonothioarsonic acid, O-cyclohexylmonothioarsonic acid, O-norbornylmonothioarsonic acid, O,O-diphenylmonothioarsonic acid, O,O-dibenzylmonothioarsonic acid, O,O-dicyclohexylmonothioarsonic acid, and O,O-
25 dinorbornylmonothioarsonic acid.

S-O Valence Stabilizer #40: Examples of heterocyclic rings containing one or two sulfur atoms and having at least one additional oxygen atom binding site not in a ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates) that meet the requirements for use as

- 30 “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-thiopheneethanol (2-(2-thienyl)ethanol); 2-propionylthiophene (1-(2-thienyl)-1-propanone); N,N’-thiobisphthalimide;

1,1'-thiocarbonyldi-2-pyridone; 2-thiopheneacetic acid; 2-thiophenecarboxaldehyde; 2-thiophenecarboxamide; 2-thiophenecarboxylic acid; 2,5-thiophenedicarboxaldehyde; 2,5-thiophenedicarboxylic acid; 2-thiophenemethanol; 2-thiophenone; thiotetronic acid; alkyl(aryl) 2-thienyl ketones; dithienyl ketone; 1,3-dithiane-2-carboxylic acid; and 1,3-dithiolane-2-carboxylic acid.

S-O Valence Stabilizer #41: Examples of heterocyclic rings containing one or two oxygen atoms and having at least one additional sulfur atom binding site not in a ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-furanethanethiol (2-(2-furyl)ethanethiol); 1-(2-furyl)-1-propanethione; 2-furanthioacetic acid; 2-furanthiocarboxaldehyde; 2-furanthiocarboxamide; 2-furanthiocarboxylic acid; 2,5-furandithiocarboxaldehyde; 2,5-furandithiocarboxylic acid; 2-furanmethanethiol; 2-furanthione; furfuryl disulfide; furfuryl mercaptan; furfuryl sulfide; and furfuryl methyl disulfide.

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S-O Valence Stabilizer #42: Examples of heterocyclic rings containing one or two sulfur atoms and having at least one additional oxygen atom binding site in a separate ring (S-O Bidentates, S-O Tridentates, S-O Tetradentates, or S-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-furyl)thiophene; 2,5-(2-furyl)thiophene; 2-(2-furyl)thiopyran; and 2,5-(2-furyl)thiopyran.

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S-O Valence Stabilizer #43: Examples of two-, three-, four-, five-, six-, seven-, eight-, nine-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol, mercapto, or thiocarbonyl groups) or oxygen (hydroxy, carboxy, or carbonyl groups) and are not contained in component heterocyclic rings (S-O Bidentates, S-O Tridentates, S-O Tetradentates, and S-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: thiaoxacyclobutane ([4]aneOS); thiaoxacyclopentane ([5]aneOS); thiaoxacyclohexane ([6]aneOS); thiaoxacycloheptane ([7]aneOS); thiaoxacyclooctane ([8]aneOS); thiaoxacyclobutene ([4]eneOS); thiaoxacyclopentene ([5]eneOS); thiaoxacyclohexene ([6]eneOS); thiaoxacycloheptene

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- ([7]eneOS); thiaoxacyclooctene ([8]eneOS); dithiaoxacyclohexane ([6]aneOS₂);
 dithiaoxacycloheptane ([7]aneOS₂); dithiaoxacyclooctane ([8]aneOS₂); dithiaoxacyclononane
 ([9]aneOS₂); dithiaoxacyclodecane ([10]aneOS₂); dithiaoxacycloundecane ([11]aneOS₂);
 dithiaoxacyclododecane ([12]aneOS₂); dithiaoxacyclohexene ([6]eneOS₂);
 5 dithiaoxacycloheptene ([7]eneOS₂); dithiaoxacyclooctene ([8]eneOS₂); dithiaoxacyclononene
 ([9]eneOS₂); dithiaoxacyclodecene ([10]eneOS₂); dithiaoxacycloundecene ([11]eneOS₂);
 dithiaoxacyclododecene ([12]eneOS₂); dithiadioxacyclooctane ([8]aneO₂S₂);
 dithiadioxacyclononane ([9]aneO₂S₂); dithiadioxacyclodecane ([10]aneO₂S₂);
 dithiadioxacycloundecane ([11]aneO₂S₂); dithiadioxacyclododecane ([12]aneO₂S₂);
 10 dithiadioxacyclotridecane ([13]aneO₂S₂); dithiadioxacyclotetradecane ([14]aneO₂S₂);
 dithiadioxacyclopentadecane ([15]aneO₂S₂); dithiadioxacyclohexadecane ([16]aneO₂S₂);
 dithiadioxacycloheptadecane ([17]aneO₂S₂); dithiadioxacyclooctadecane ([18]aneO₂S₂);
 dithiadioxacyclononadecane ([19]aneO₂S₂); dithiadioxacycloeicosane ([20]aneO₂S₂);
 dithiadioxacyclooctadiene ([8]dieneO₂S₂); dithiadioxacyclononadiene ([9]dieneO₂S₂);
 15 dithiadioxacyclodecadiene ([10]dieneO₂S₂); dithiadioxacycloundecadiene ([11]dieneO₂S₂);
 dithiadioxacyclododecadiene ([12]dieneO₂S₂); dithiadioxacyclotridecadiene ([13]dieneO₂S₂);
 dithiadioxacyclotetradecadiene ([14]dieneO₂S₂); dithiadioxacyclopentadecadiene
 ([15]dieneO₂S₂); dithiadioxacyclohexadecadiene ([16]dieneO₂S₂);
 dithiadioxacycloheptadecadiene ([17]dieneO₂S₂); dithiadioxacyclooctadecadiene
 20 ([18]dieneO₂S₂); dithiadioxacyclononadecadiene ([19]dieneO₂S₂); and
 dithiadioxacycloeicosadiene ([20]dieneO₂S₂).

- S-O Valence Stabilizer #44: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-
 membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands,
 25 cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur or
 oxygen and are contained in component heterocyclic rings (S-O Tridentates, S-O Tetridentates,
 or S-O Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for
 Ce⁺⁴ include, but are not limited to: difurandithiophenes; difurantrithiophenes;
 trifurantrithiophenes; and tetrafurantetrathiophenes.

S-O Valence Stabilizer #45: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur or oxygen and are contained in a combination of heterocyclic rings and thiol, mercapto,

- 5 thiocarbonyl, hydroxy, carboxy, and carbonyl groups (S-O Tridentates, S-O Tetracentates, or S-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dithiadifurandithiophenes; tetrathiadifurandithiophenes; trithiatrifurantrithiophenes; trithiatrifurantrithiophenes; tetrathiatetrafurantetrathiophenes; and octathiatetrafurantetrathiophenes.

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S-O Valence Stabilizer #46: Examples of sulfoxides that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dimethylsulfoxide (DMSO); diethylsulfoxide; diphenylsulfoxide; and tetrahydrothiophene oxide.

- 15 S-O Valence Stabilizer #47: Examples of sulfones that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dimethyl sulfone; diethyl sulfone; and diphenyl sulfone.

- 20 S-O Valence Stabilizer #48: Examples of sulfur dioxide ligands that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: sulfur dioxide ($-SO_2$) ligands. [Note: sulfur dioxide is a reducing agent, and complexed metal ions therefore tend to prefer lower oxidation states.]

- 25 N-P Valence Stabilizer #1: Examples of aminoaryl phosphines and iminoaryl phosphines (N-P Bidentates, N-P Tridentates, and N-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-aminophenyl)phosphine; tri(2-aminophenyl)phosphine oxide; and tri(2-aminophenyl)phosphine sulfide.

- 30 N-P Valence Stabilizer #2: Examples of heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional phosphorus atom binding site not in a ring (N-P

Bidentates, N-P Tridentates, N-P Tetracentates, or N-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-imidazolyl)phosphine; tri(2-pyrrolyl)phosphine; tri(2-pyridyl)phosphine; tri(2-imidazolyl)phosphine oxide; tri(2-pyrrolyl)phosphine oxide; tri(2-pyridyl)phosphine oxide; tri(2-imidazolyl)phosphine sulfide; tri(2-pyrrolyl)phosphine sulfide; and tri(2-pyridyl)phosphine sulfide.

N-P Valence Stabilizer #3: Examples of heterocyclic rings containing one, two, or three phosphorus atoms and having at least one additional nitrogen atom binding site not in a ring (N-P Bidentates, N-P Tridentates, N-P Tetracentates, or N-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-aminophosphole; 2,5-diaminophosphole; 2-(aminomethyl)phosphole; 2,5-di(aminomethyl)phosphole; 2-aminophosphorin; 2,6-diaminophosphorin; 2-(aminomethyl)phosphorin; 2,6-di(aminomethyl)phosphorin; triaminocyclotriphosphazenes; and hexaminocyclotriphosphazenes.

N-P Valence Stabilizer #4: Examples of heterocyclic rings containing one, two, three, or four nitrogen atoms and having at least one additional phosphorus atom binding site in a separate ring (N-P Bidentates, N-P Tridentates, N-P Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-pyrrolyl)phosphole; 2,5-di(2-pyrrolyl)phosphole; 2-(2-pyridyl)phosphorin; and 2,6-(2-pyridyl)phosphorin.

N-P Valence Stabilizer #5: Examples of two-, three-, four-, five-, six-, seven-, eight-, nine-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen (usually amine or imine groups) or phosphorus and are not contained in component heterocyclic rings (N-P Bidentates, N-P Tridentates, N-P Tetracentates, and N-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclobiphosphazenes; cyclotriphosphazenes; cyclotetraphosphazenes; cyclopentaphosphazenes;

cyclohexaphosphazenes; diphosphatetraazacyclooctatetraenes; diphospha-s-triazines; and phospho-s-triazines.

N-P Valence Stabilizer #6: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered

- 5 macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or phosphorus and are contained in component heterocyclic rings (N-P Bidentates, N-P Tridentates, N-P Tetradentates, or N-P Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diphospholedipyrroles;
- 10 diphosphorindipyridines; triphospholetripyrroles; triphosphorintripyridines; tetraphospholetetrapyrroles; and tetraphosphorintetrapyridines.

N-P Valence Stabilizer #7: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands,

- 15 cyclidenes, and sepulchrates) wherein all binding sites are composed of nitrogen or phosphorus and are contained in a combination of heterocyclic rings and amine, imine, and phosphine groups (N-P Bidentates, N-P Tridentates, N-P Tetradentates, or N-P Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: azaphosphatetraphyrins; diazadiphosphatetraphyrins; azaphosphahexaphyrins;
- 20 diazadiphosphahexaphyrins; triazatriphosphahexaphyrins; and apholate.

S-P Valence Stabilizer #1: Examples of thioaryl phosphines (S-P Bidentates, S-P Tridentates, S-P Tetradentates, and S-P Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-mercaptophenyl)phosphine; tri(2-

- 25 mercaptophenyl)phosphine oxide; and tri(2-mercaptophenyl)phosphine sulfide..

S-P Valence Stabilizer #2: Examples of heterocyclic rings containing one or two sulfur atoms and having at least one additional phosphorus atom binding site not in a ring (S-P Bidentates, S-P Tridentates, S-P Tetradentates, or S-P Hexadentates) that meet the requirements for use as

30 “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-thiophene)phosphine; tri(2-thiopyran)phosphine; tri(2-thiophene)phosphine oxide; tri(2-

thiopyran)phosphine oxide; tri(2-thiophene)phosphine sulfide; and tri(2-thiopyran)phosphine sulfide.

S-P Valence Stabilizer #3: Examples of heterocyclic rings containing one, two, or three

- 5 phosphorus atoms and having at least one additional sulfur atom binding site not in a ring (S-P Bidentates, S-P Tridentates, S-P Tetracentates, or S-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-mercaptophosphole; 2,5-dimercaptophosphole; 2-(mercaptomethyl)phosphole; 2,5-di(mercaptomethyl)phosphole; 2-mercaptophosphorin; 2,6-dimercaptophosphorin; 2-
10 (mercaptomethyl)phosphorin; and 2,6-di(mercaptomethyl)phosphorin.

S-P Valence Stabilizer #4: Examples of heterocyclic rings containing one or two sulfur atoms and having at least one additional phosphorus atom binding site in a separate ring (S-P

- Bidentates, S-P Tridentates, S-P Tetracentates) that meet the requirements for use as “narrow
15 band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-thienyl)phosphole; 2,5-di(2-thienyl)phosphole; 2-(2-thienyl)phosphorin; and 2,6-(2-thienyl)phosphorin.

S-P Valence Stabilizer #5: Examples of two-, three-, four-, five-, six-, seven-, eight-, nine-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands,

- 20 cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur (usually thiol, mercapto, or thiocarbonyl groups) or phosphorus and are not contained in component heterocyclic rings (S-P Bidentates, S-P Tridentates, S-P Tetracentates, and S-P Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphathiacyclobutane ([4]anePS); phosphathiacyclopentane
25 ([5]anePS); phosphathiacyclohexane ([6]anePS); phosphathiacycloheptane ([7]anePS); phosphathiacyclooctane ([8]anePS); diphosphathiacyclohexane ([6]aneSP₂); diphosphathiacycloheptane ([7]aneSP₂); diphosphathiacyclooctane ([8]aneSP₂); diphosphathiacyclononane ([9]aneSP₂); diphosphathiacyclodecane ([10]aneSP₂); diphosphathiacycloundecane ([11]aneSP₂); diphosphathiacyclododecane ([12]aneSP₂);
30 diphosphadithiacyclooctane ([8]aneS₂P₂); diphosphadithiacyclononane ([9]aneS₂P₂); diphosphadithiacyclodecane ([10]aneS₂P₂); diphosphadithiacycloundecane ([11]aneS₂P₂);

diphosphadithiacyclododecane ([12]aneS₂P₂); diphosphadithiacyclotridecane ([13]aneS₂P₂);
diphosphadithiacyclotetradecane ([14]aneS₂P₂); diphosphadithiacyclopentadecane ([15]aneS₂P₂);
diphosphadithiacyclohexadecane ([16]aneS₂P₂); diphosphadithiacycloheptadecane
([17]aneS₂P₂); diphosphadithiacyclooctadecane ([18]aneS₂P₂); diphosphadithiacyclononadecane
5 ([19]aneS₂P₂); diphosphadithiacycloeicosane ([20]aneS₂P₂).

S-P Valence Stabilizer #6: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered
macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands,
cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur or phosphorus and
10 are contained in component heterocyclic rings (S-P Bidentates, S-P Tridentates, S-P
Tetradentates, or S-P Hexadentates) that meet the requirements for use as “narrow band” valence
stabilizers for Ce⁺⁴ include, but are not limited to: diphospholedithiophenes;
diphosphorindithiopyrans; triphospholetrithiophenes; triphosphorintrithiopyrans;
tetraphospholetetrathiophenes; and tetraphosphorintetrathiopyrans.

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S-P Valence Stabilizer #7: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered
macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands,
cyclidenes, and sepulchrates) wherein all binding sites are composed of sulfur or phosphorus and
are contained in a combination of heterocyclic rings and thiol, mercapto, thiocarbonyl, and
20 phosphine groups (S-P Bidentates, S-P Tridentates, S-P Tetradentates, or S-P Hexadentates) that
meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not
limited to: thiaphosphatetraphyrins; dithiadiphosphatetraphyrins; thiaphosphahexaphyrins;
dithiadiphosphahexaphyrins; and trithiatriphosphahexaphyrins.

25 P-O Valence Stabilizer #1: Examples of hydroxyaryl phosphines (P-O Bidentates, P-O
Tridentates, P-O Tetradentates, and P-O Hexadentates) that meet the requirements for use as
“narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: tri(2-
hydroxyphenyl)phosphine; tri(2-hydroxyphenyl)phosphine oxide; and tri(2-
hydroxyphenyl)phosphine sulfide.

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P-O Valence Stabilizer #2: Examples of heterocyclic rings containing one or two oxygen atoms and having at least one additional phosphorus atom binding site not in a ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates, or P-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tri(2-furan)phosphine; tri(2-pyran)phosphine; tri(2-furan)phosphine oxide; tri(2-pyran)phosphine oxide; tri(2-furan)phosphine sulfide; and tri(2-pyran)phosphine sulfide.

P-O Valence Stabilizer #3: Examples of heterocyclic rings containing one, two, or three phosphorus atoms and having at least one additional oxygen atom binding site not in a ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates, or P-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-hydroxyphosphole; 2,5-dihydroxyphosphole; 2-(hydroxymethyl)phosphole; 2,5-di(hydroxymethyl)phosphole; 2-hydroxyphosphorin; 2,6-dihydroxyphosphorin; 2-(hydroxymethyl)phosphorin; and 2,6-di(hydroxymethyl)phosphorin.

P-O Valence Stabilizer #4: Examples of heterocyclic rings containing one or two oxygen atoms and having at least one additional phosphorus atom binding site in a separate ring (P-O Bidentates, P-O Tridentates, P-O Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(2-furyl)phosphole; 2,5-di(2-furyl)phosphole; 2-(2-furyl)phosphorin; and 2,6-(2-furyl)phosphorin.

P-O Valence Stabilizer #5: Examples of two-, three-, four-, five-, six-, seven-, eight-, nine-, and ten-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen (usually hydroxy, carboxy, or carbonyl groups) or phosphorus and are not contained in component heterocyclic rings (P-O Bidentates, P-O Tridentates, P-O Tetracentates, and P-O Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: phosphaoxacyclobutane ([4]anePO); phosphaoxacyclopentane ([5]anePO); phosphaoxacyclohexane ([6]anePO); phosphaoxacycloheptane ([7]anePO); phosphaoxacyclooctane ([8]anePO); diphosphaoxacyclohexane ([6]aneOP₂); diphosphaoxacycloheptane ([7]aneOP₂); diphosphaoxacyclooctane ([8]aneOP₂);

- diphosphaoxacyclononane ([9]aneOP₂); diphosphaoxacyclodecane ([10]aneOP₂);
diphosphaoxacycloundecane ([11]aneOP₂); diphosphaoxacyclododecane ([12]aneOP₂);
diphosphadioxacyclooctane ([8]aneO₂P₂); diphosphadioxacyclononane ([9]aneO₂P₂);
diphosphadioxacyclodecane ([10]aneO₂P₂); diphosphadioxacycloundecane ([11]aneO₂P₂);
5 diphosphadioxacyclododecane ([12]aneO₂P₂); diphosphadioxacyclotridecane ([13]aneO₂P₂);
diphosphadioxacyclotetradecane ([14]aneO₂P₂); diphosphadioxacyclopentadecane
([15]aneO₂P₂); diphosphadioxacyclohexadecane ([16]aneO₂P₂);
diphosphadioxacycloheptadecane ([17]aneO₂P₂); diphosphadioxacyclooctadecane
([18]aneO₂P₂); diphosphadioxacyclononadecane ([19]aneO₂P₂); diphosphadioxacycloeicosane
10 ([20]aneO₂P₂); and dioxaphospholane.

- P-O Valence Stabilizer #6: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered
macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands,
cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen or phosphorus
15 and are contained in component heterocyclic rings (P-O Bidentates, P-O Tridentates, P-O
Tetradentates, or P-O Hexadentates) that meet the requirements for use as “narrow band” valence
stabilizers for Ce⁺⁴ include, but are not limited to: diphospholedifurans; diphosphorindipyrans;
triphospholettrifurans; triphosphorintripyrans; tetraphospholettetrafurans; and
tetraphosphorintetrapyrans.

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- P-O Valence Stabilizer #7: Examples of four-, five-, six-, seven-, eight-, nine-, or ten-membered
macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands,
cyclidenes, and sepulchrates) wherein all binding sites are composed of oxygen or phosphorus
and are contained in a combination of heterocyclic rings and hydroxy, carboxy, carbonyl, and
25 phosphine groups (P-O Bidentates, P-O Tridentates, P-O Tetradentates, or P-O Hexadentates)
that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are
not limited to: oxaphosphatetraphyrins; dioxadiphosphatetraphyrins; oxaphosphahexaphyrins;
dioxadiphosphahexaphyrins; and trioxatriphosphahexaphyrins.

- 30 As Valence Stabilizer #1: Examples of monoarsines (As Monodentates) that meet the
requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:

arsine, triphenylarsine, ticyclohexylarsine, methyldiphenylarsine, ethyldiphenylarsine, arsinonorbormane, and arsinoadamantane.

As Valence Stabilizer #2: Examples of diarsines (As Monodentates or As-As Bidentates) that

- 5 meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: bis(diphenylarsino)methane, bis(diphenylarsino)ethane, bis(diphenylarsino)propane, bis(diphenylarsino)butane, bis(diphenylarsino)pentane, 1,2-diarsinobenzene, cyclohexane-1,2-diarsine, 1,2-bis(phenylbutylarsino)ethane, o-phenylenebis(methylphenylarsine) and o-phenylenebis(dimethylarsine) (diars). [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]
- 10

As Valence Stabilizer #3: Examples of triarsines (As-As Bidentates, or As-As Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,1,5,9,9-pentaphenyl-1,5,9-triarsanonane, 3-methyl-3-(As,As-

- 15 dimethyl)arsinomethyl-1,1,5,5-tetraphenyl-1,5-diarsapentane, As,As-[o-(As-dimethyl)arsinodiphenyl]-(As-phenyl)arsine, As,As-[o-(As-diphenyl)arsinodiphenyl]-(As-phenyl)arsine, hexahydro-2,4,6-trimethyl-1,3,5-triarsinazine. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]
- 20

As Valence Stabilizer #4: Examples of tetraarsines (As-As Bidentates, As-As Tridentates, or As-As Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 3,3-(As-diphenyl)arsinomethyl-1,1,5,5-tetraphenyl-1,5-diarsapentane. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-

- 25 sensitive and therefore unsuitable for these applications.]

As Valence Stabilizer #5: Examples of pentaarsines (As-As Bidentates, As-As Tridentates, or As-As Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 4-[2-(As-diphenyl)arsinoethyl]-1,1,7,10,10-pentaphenyl-

30 1,4,7,10-tetraarsadecane. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

As Valence Stabilizer #6: Examples of hexaarsines (As-As Bidentates, As-As Tridentates, As-As Tetridentates, or As-As Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: o-phenylenebis[di-3-(As-diphenyl)arsinopropylarsine]. [Note: the aryl derivatives are air-stable, whereas the alkyl derivatives are air-sensitive and therefore unsuitable for these applications.]

As Valence Stabilizer #7: Examples of 5-membered heterocyclic rings containing one arsenic atom (As Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: arsole, azarsole, diazarsole, benzarsole, benzazarsole, dibenzarsole, naphtharsole, naphthazarsole.

As Valence Stabilizer #8: Examples of 6-membered heterocyclic rings containing one arsenic atom (As Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: arsenin, azarsenin, diazarsenin, benzarsenin, benzazarsenin, dibenzarsenin, naphtharsenin, and naphthazarsenin.

As Valence Stabilizer #9: Examples of 5-membered heterocyclic rings containing one arsenic atom and having at least one additional arsenic atom binding site not contained in a ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetridentates, or As-As Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(As-phenylarsino)arsole; 2,5-(As-phenylarsino)arsole; 2-(As-phenylarsino)benzarsole; 7-(As-phenylarsino)benzarsole; and 1,8-(As-phenylarsino)dibenzarsole.

As Valence Stabilizer #10: Examples of 6-membered heterocyclic rings containing one arsenic atom and having at least one additional arsenic atom binding site not contained in a ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetridentates, or As-As Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2-(As-phenylarsino)arsenin; 2,5-(As-phenylarsino)arsenin; 2-(As-phenylarsino)benzarsenin; 7-(As-phenylarsino)benzarsenin; and 1,9-(As-phenylarsino)dibenzarsenin.

As Valence Stabilizer #11: Examples of 5-membered heterocyclic rings containing one arsenic atom and having at least one additional arsenic atom binding site contained in a ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

- 5 2,2'-biarsole; 2,2',2''-triarsole; and 2,2'-bibenzarsole.

As Valence Stabilizer #12: Examples of 6-membered heterocyclic rings containing one arsenic atom and having at least one additional arsenic atom binding site contained in a ring (As Monodentates, As-As Bidentates, As-As Tridentates, As-As Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:

10 2,2'-biarsenin; 2,2',2''-triarсенin; 2,2',2'',2'''-tetraarsenin; 2,2'-bibenzarsenin; and 8,8'-bibenzarsenin.

As Valence Stabilizer #13a: Examples of two-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein both binding sites are composed of arsenic and are not contained in component heterocyclic rings (As-As Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: As,As-diphenyldiarsacyclobutane ([4]aneAs₂); As,As-diphenyldiarsacyclopentane ([5]aneAs₂); As,As-diphenyldiarsacyclohexane ([6]aneAs₂); As,As-diphenyldiarsacycloheptane ([7]aneAs₂); As,As-diphenyldiarsacyclooctane ([8]aneAs₂); As,As-diphenyldiarsacyclobutene ([4]eneAs₂); As,As-diphenyldiarsacyclopentene ([5]eneAs₂); As,As-diphenyldiarsacyclohexene ([6]eneAs₂); As,As-diphenyldiarsacycloheptene ([7]eneAs₂); and As,As-diphenyldiarsacyclooctene ([8]eneAs₂).

- 25 As Valence Stabilizer #13b: Examples of three-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of arsenic and are not contained in component heterocyclic rings (As-As Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: As,As,As-triphenyltriarsacyclohexane ([6]aneAs₃); As,As,As-triphenyltriarsacycloheptane ([7]aneAs₃); As,As,As-triphenyltriarsacyclooctane ([8]aneAs₃); As,As,As-triphenyltriarsacyclononane ([9]aneAs₃); As,As,As-triphenyltriarsacyclodecane
- 30

5 ([10]aneAs₃); As,As,As-triphenyltriarsacycloundecane ([11]aneAs₃); As,As,As-triphenyltriarsacyclododecane ([12]aneAs₃); As,As,As-triphenyltriarsacyclohexatriene ([6]trieneAs₃); As,As,As-triphenyltriarsacycloheptatriene ([7]trieneAs₃); As,As,As-triphenyltriarsacyclooctatriene ([8]trieneAs₃); As,As,As-triphenyltriarsacyclononatriene ([9]trieneAs₃); As,As,As-triphenyltriarsacyclodecatriene ([10]trieneAs₃); As,As,As-triphenyltriarsacycloundecatriene ([11]trieneAs₃); and As,As,As-triphenyltriarsacyclododecatriene ([12]trieneAs₃).

10 As Valence Stabilizer #13c: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of arsenic and are not contained in component heterocyclic rings (As-As Tetrudentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: As,As,As,As-tetraphenyltetraarsacyclooctane ([8]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclononane ([9]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclodecane ([10]aneAs₄); As,As,As,As-tetraphenyltetraarsacycloundecane ([11]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclododecane ([12]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclotridecane ([13]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclotetradecane ([14]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclopentadecane ([15]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclohexadecane ([16]aneAs₄); As,As,As,As,As-tetraphenyltetraarsacycloheptadecane ([17]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclooctadecane ([18]aneAs₄); As,As,As,As-tetraphenyltetraarsacyclononadecane ([19]aneAs₄); and As,As,As,As-tetraphenyltetraarsacycloeicosane ([20]aneAs₄).

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As Valence Stabilizer #13d: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of arsenic and are not contained in component heterocyclic rings (As-As Tridentates, As-As Tetrudentates, or As-As Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: As,As,As,As,As,As-hexaphenylhexaarsacyclododecane ([12]aneAs₆); As-As,As,As,As,As,As-

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hexaphenylhexaarsacyclotridecane ([13]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclotetradecane ([14]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclopentadecane ([15]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclohexadecane ([16]aneAs₆); As,As,As,As,As,As-
5 hexaphenylhexaarsacycloheptadecane ([17]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclooctadecane ([18]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclononadecane ([19]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacycloeicosane ([20]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacycloheneicosane ([21]aneAs₆); As,As,As,As,As,As-
10 hexaphenylhexaarsacyclodocosane ([22]aneAs₆); As,As,As,As,As,As-
hexaphenylhexaarsacyclotricosane ([23]aneAs₆); and As,As,As,As,As,As-
hexaphenylhexaarsacyclotetracosane ([24]aneAs₆).

As Valence Stabilizer #14a: Examples of four-membered macrocyclics, macrobicyclics, and
15 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
four binding sites are composed of arsenic and are contained in component 5-membered
heterocyclic rings (As-As Tetrudentates) that meet the requirements for use as “narrow band”
valence stabilizers for Ce⁺⁴ include, but are not limited to: tetraarsoles.

20 As Valence Stabilizer #14b: Examples of six-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
six binding sites are composed of arsenic and are contained in component 5-membered
heterocyclic rings (As-As Tetrudentates and As-As Hexadentates) that meet the requirements for
use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to: hexaarsoles.

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As Valence Stabilizer #15a: Examples of four-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
four binding sites are composed of arsenic and are contained in a combination of 5-membered
heterocyclic rings and arsine groups (As-As Tridentates, As-As Tetrudentates) that meet the
30 requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
diarsatetraarsoles; and tetraarsatetraarsoles.

As Valence Stabilizer #15b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of arsenic and are contained in a combination of 5-membered heterocyclic rings and phosphine groups (As-As Tridentates, As-As Tetracentates, and As-As
5 Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diarsahexaarsoles; and triarsahexaarsoles.

As Valence Stabilizer #16a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
10 four binding sites are composed of arsenic and are contained in component 6-membered heterocyclic rings (As-As Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclotetraarsenins.

As Valence Stabilizer #16b: Examples of six-membered macrocyclics, macrobicyclics, and
15 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of arsenic and are contained in component 6-membered heterocyclic rings (As-As Tridentates, As-As Tetracentates, and As-As Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclohexaarsenins.

As Valence Stabilizer #17a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of arsenic and are contained in a combination of 6-membered heterocyclic rings and arsine groups (As-As Tridentates, As-As Tetracentates, or As-As
25 Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diarsacyclotetraarsenins; and tetraarsacyclotetraarsenins.

As Valence Stabilizer #17b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
30 six binding sites are composed of arsenic and are contained in a combination of 6-membered heterocyclic rings and arsine groups (As-As Tridentates, As-As Tetracentates, or As-As

Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diarsacyclohexaarsenins; and triarsacyclohexaarsenins.

Se Valence Stabilizer #1: Examples of monoselenoethers (Se Monodentates) that meet the

5 requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hydrogen selenide, dimethyl selenide, diethyl selenide, dioctyl selenide, diphenyl selenide, dicyclohexyl selenide, tetramethylene selenide, trimethylene selenide, dimethylene selenide, and selenobicycloheptane.

10 Se Valence Stabilizer #2: Examples of diselenoethers (Se Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,5-dimethyl-3,6-diselenaooctane; 2,5-diselenaohexane; 2,6-diselenaheptane; 3,7-diselenaanonane; 3,6-diselenaooctane; 3-butenyl butyl selenoether (bbs); 4-pentenyl butyl selenoether (pbs); 3-butenyl phenyl selenoether (bps); and 4-pentenyl phenyl selenoether (pps).

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Se Valence Stabilizer #3: Examples of triselenoethers (Se Bidentates or Se Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,3,5-triselenane; 2,5,8-triselenanonane; 3,6,9-triselenaundecane; and 2,6,10-triselenaundecane.

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Se Valence Stabilizer #4: Examples of tetraselenoethers (Se Bidentates, Se Tridentates, or Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,6,10,14-tetraselenapentadecane and 2,5,8,11-tetraselenadodecane.

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Se Valence Stabilizer #5a: Examples of 5-membered heterocyclic rings containing one selenium atom (Se Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydroselenophene, selenophene, selenazole, selenapyrroline, selenaphospholene, selenaphosphole, oxaselenole, selenadiazole, selenatriazole, benzodihydroselenophene, benzoselenophene, benzoselenazole, benzoselenaphosphole, dibenzoselenophene, and naphthoselenophene.

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Se Valence Stabilizer #5b: Examples of 5-membered heterocyclic rings containing two selenium atoms (Se Monodentates or Se Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenole, benzodiselenole, and naphthodiselenole.

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Se Valence Stabilizer #6a: Examples of 6-membered heterocyclic rings containing one selenium atom (Se Monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydroselenopyran, selenopyran, selenazine, selenadiazine, selenaphosphorin, selenadiphosphorin, oxaselenin, benzoselenopyran, dibenzoselenopyran, and naphthoselenopyran.

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Se Valence Stabilizer #6b: Examples of 6-membered heterocyclic rings containing two selenium atoms (Se Monodentates or Se Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dihydrodiselenin, diselenin,

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benzodiselenin, dibenzodiselenin, and naphthodiselenin.

Se Valence Stabilizer #7: Examples of 5-membered heterocyclic rings containing one selenium atom and having at least one additional selenium atom binding site not contained in a ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,5-diseleno-2,5-dihydroselenophene; 2,5-bis(selenomethyl)-2,5-dihydroselenophene; 2,5-bis(2-selenophenyl)-2,5-dihydroselenophene; 2,5-diseleno(selenophene); 2,5-bis(selenomethyl)selenophene; 2,5-bis(2-selenophenyl)selenophene; 2,5-diseleno(selenazole); 2,5-bis(selenomethyl)selenazole; 2,5-bis(2-selenophenyl)selenazole; and 2,5-diseleno-1,3,4-selenadiazole [bismuthselenol].

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Se Valence Stabilizer #8: Examples of 6-membered heterocyclic rings containing one selenium atom and having at least one additional selenium atom binding site not contained in a ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,6-diseleno-2,5-dihydroselenopyran; 2,6-bis(selenomethyl)-2,5-

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dihydroselenopyran; 2,6-bis(2-selenophenyl)-2,5-dihydroselenopyran; 2,6-diseleno(selenopyran); 2,6-bis(selenomethyl)selenopyran; 2,6-bis(2-selenophenyl)selenopyran; 2,6-diseleno(selenazine); 2,6-bis(selenomethyl)selenazine; 2,6-bis(2-selenophenyl)selenazine; 2,6-diseleno-1,3,5-selenadiazine; 2-seleno-1-benzoselenopyran; 8-seleno-1-benzoselenopyran; 5 and 1,9-diselenodibenzoselenopyran.

Se Valence Stabilizer #9: Examples of 5-membered heterocyclic rings containing one selenium atom and having at least one additional selenium atom binding site contained in a ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2,5-dihydroselenophene; 2,2',2''-tri-2,5-dihydroselenophene; 2,2'-biselenophene; 2,2',2''-triselenophene; 2,2'-biselenazole; 5,5'-biselenazole; 2,2'-bi-1,3,4-selenadiazole; 2,2'-biselenanaphthene; 2,2'-bibenzoselenazole; and 1,1'-bis(dibenzoselenophene).

Se Valence Stabilizer #10: Examples of 6-membered heterocyclic rings containing one selenium atom and having at least one additional selenium atom binding site contained in a ring (Se Monodentates, Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 2,2'-bi-2,5-dihydroselenopyran; 2,2',2''-tri-2,5-dihydroselenopyran; 2,2'-biselenopyran; 2,2',2''-triselenopyran; 2,2'-bi-1,4-selenazine; 2,2'-bi-1,3,5-selenadiazine; 2,2'-bi-1-benzoselenopyran; and 1,1'-bis(dibenzoselenopyran).

Se Valence Stabilizer #11a: Examples of two-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein both binding sites are composed of selenium (usually selenol or selenoether groups) and are not contained in component heterocyclic rings (Se-Se Bidentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenacyclobutane ([4]aneSe₂); diselenacyclopentane ([5]aneSe₂); diselenacyclohexane ([6]aneSe₂); diselenacycloheptane ([7]aneSe₂); diselenacyclooctane ([8]aneSe₂); diselenacyclobutene ([4]eneSe₂); diselenacyclopentene ([5]eneSe₂); diselenacyclohexene ([6]eneSe₂); diselenacycloheptene ([7]eneSe₂); diselenacyclooctene ([8]eneSe₂); diselenacyclobutadiene

([4]dieneSe₂); diselenacyclopentadiene ([5]dieneSe₂); diselenacyclohexadiene ([6]dieneSe₂); diselenacycloheptadiene ([7]dieneSe₂); and diselenacyclooctadiene ([8]dieneSe₂).

Se Valence Stabilizer #11b: Examples of three-membered macrocyclics, macrobicyclics, and

- 5 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of selenium (usually selenol or selenoether groups) and are not contained in component heterocyclic rings (Se-Se Tridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
- triselenacyclohexane ([6]aneSe₃); triselenacycloheptane ([7]aneSe₃); triselenacyclooctane
10 ([8]aneSe₃); triselenacyclononane ([9]aneSe₃); triselenacyclodecane ([10]aneSe₃);
triselenacycloundecane ([11]aneSe₃); triselenacyclododecane ([12]aneSe₃); triselenacyclohexene
([6]eneSe₃); triselenacycloheptene ([7]eneSe₃); triselenacyclooctene ([8]eneSe₃);
triselenacyclononene ([9]eneSe₃); triselenacyclodecene ([10]eneSe₃); triselenacycloundecene
([11]eneSe₃); triselenacyclododecene ([12]eneSe₃); triselenacyclohexatriene ([6]trieneSe₃);
15 triselenacycloheptatriene ([7]trieneSe₃); triselenacyclooctatriene ([8]trieneSe₃);
triselenacyclononatriene ([9]trieneSe₃); triselenacyclodecatriene ([10]trieneSe₃);
triselenacycloundecatriene ([11]trieneSe₃); and triselenacyclododecatriene ([12]trieneSe₃).

Se Valence Stabilizer #11c: Examples of four-membered macrocyclics, macrobicyclics, and

- 20 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all binding sites are composed of selenium (usually selenol or selenoether groups) and are not contained in component heterocyclic rings (Se-Se Tetrudentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴ include, but are not limited to:
- tetraselenacyclooctane ([8]aneSe₄); tetraselenacyclononane ([9]aneSe₄); tetraselenacyclodecane
25 ([10]aneSe₄); tetraselenacycloundecane ([11]aneSe₄); tetraselenacyclododecane ([12]aneSe₄);
tetraselenacyclotridecane ([13]aneSe₄); tetraselenacyclotetradecane ([14]aneSe₄);
tetraselenacyclopentadecane ([15]aneSe₄); tetraselenacyclohexadecane ([16]aneSe₄);
tetraselenacycloheptadecane ([17]aneSe₄); tetraselenacyclooctadecane ([18]aneSe₄);
tetraselenacyclononadecane ([19]aneSe₄); tetraselenacycloeicosane ([20]aneSe₄);
30 tetraselenacyclooctadiene ([8]dieneSe₄); tetraselenacyclononadiene ([9]dieneSe₄);
tetraselenacyclodecadiene ([10]dieneSe₄); tetraselenacycloundecadiene ([11]dieneSe₄);

tetraselenacyclododecadiene ([12]dieneSe₄); tetraselenacyclotridecadiene ([13]dieneSe₄);
tetraselenacyclotetradecadiene ([14]dieneSe₄); tetraselenacyclopentadecadiene ([15]dieneSe₄);
tetraselenacyclohexadecadiene ([16]dieneSe₄); tetraselenacycloheptadecadiene ([17]dieneSe₄);
tetraselenacyclooctadecadiene ([18]dieneSe₄); tetraselenacyclononadecadiene ([19]dieneSe₄);
5 tetraselenacycloeicosadiene ([20]dieneSe₄); tetraselenacyclooctatetradiene ([8]tetradieneSe₄);
tetraselenacyclononatetradiene ([9]tetradieneSe₄); tetraselenacyclodecatetradiene
([10]tetradieneSe₄); and tetraselenacycloundecatetradiene ([11]tetradieneSe₄).

Se Valence Stabilizer #11d: Examples of six-membered macrocyclics, macrobicyclics, and
10 macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
binding sites are composed of selenium (usually selenol or selenoether groups) and are not
contained in component heterocyclic rings (Se-Se Tridentates, Se-Se Tetridentates, or Se-Se
Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce⁺⁴
include, but are not limited to: hexaselenacyclododecane ([12]aneSe₆); hexaselenacyclotridecane
15 ([13]aneSe₆); hexaselenacyclotetradecane ([14]aneSe₆); hexaselenacyclopentadecane
([15]aneSe₆); hexaselenacyclohexadecane ([16]aneSe₆); hexaselenacycloheptadecane
([17]aneSe₆); hexaselenacyclooctadecane ([18]aneSe₆); hexaselenacyclononadecane
([19]aneSe₆); hexaselenacycloeicosane ([20]aneSe₆); hexaselenacycloheneicosane ([21]aneSe₆);
hexaselenacyclodocosane ([22]aneSe₆); hexaselenacyclotricosane ([23]aneSe₆);
20 hexaselenacyclotetracosane ([24]aneSe₆); hexaselenacyclododecatriene ([12]trieneSe₆);
hexaselenacyclotridecatriene ([13]trieneSe₆); hexaselenacyclotetradecatriene ([14]trieneSe₆);
hexaselenacyclopentadecatriene ([15]trieneSe₆); hexaselenacyclohexadecatriene ([16]trieneSe₆);
hexaselenacycloheptadecatriene ([17]trieneSe₆); and hexaselenacyclooctadecatriene
([18]trieneSe₆).

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Se Valence Stabilizer #12a: Examples of four-membered macrocyclics, macrobicyclics, and
macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all
four binding sites are composed of selenium and are contained in component 5-membered
heterocyclic rings (Se-Se Tetridentates) that meet the requirements for use as “narrow band”
30 valence stabilizers for Ce⁺⁴ include, but are not limited to: tetraselenophenes;
tetraselenaphospholes; tetraoxaselenoles; and tetradiselenoles.

Se Valence Stabilizer #12b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of selenium and are contained in component 5-membered heterocyclic rings (Se-Se Tridentates or Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hexaselenophenes; hexaselenophospholes; hexaoxaselenoles; and hexadiselenoles.

Se Valence Stabilizer #13a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of selenium and are contained in a combination of 5-membered heterocyclic rings and selenol and selenoether groups (Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenatetraselenophenes; tetraselenatetraselenophenes; diselenatetradiselenoles; and tetraselenatetradiselenoles.

Se Valence Stabilizer #13b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of selenium and are contained in a combination of 5-membered heterocyclic rings and selenol or selenoether groups (Se-Se Tridentates or Se-Se Hexacentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenahexaselenophenes; and triselenahexaselenophenes.

Se Valence Stabilizer #14a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of selenium and are contained in component 6-membered heterocyclic rings (Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetraselenopyrans; tetraselenaphosphorins; tetraselenadiphosphorins; tetraoxaselenins; and tetradiselenins.

Se Valence Stabilizer #14b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all

six binding sites are composed of selenium and are contained in component 6-membered heterocyclic rings (Se-Se Tridentates or Se-Se Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hexaselenopyrans; hexaselenaphosphorins; hexaselenadiphosphorins; hexaoxaselenins; and hexadiselenins.

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Se Valence Stabilizer #15a: Examples of four-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all four binding sites are composed of selenium and are contained in a combination of 6-membered heterocyclic rings and selenol or selenoether groups (Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenatetraselenopyrans; tetraselenatetraselenopyrans; diselenatetraselenaphosphorins; tetraselenatetraselenaphosphorins; diselenatetraoxaselenins; tetraselenatetraoxaselenins; diselenatetradiselenins; and tetraselenatetradiselenins.

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Se Valence Stabilizer #15b: Examples of six-membered macrocyclics, macrobicyclics, and macropolycyclics (including catapinands, cryptands, cyclidenes, and sepulchrates) wherein all six binding sites are composed of selenium and are contained in a combination of 6-membered heterocyclic rings and selenol or selenoether groups (Se-Se Tridentates, Se-Se Tetracentates, or Se-Se Hexadentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenahexaselenopyrans; triselenahexaselenopyrans; diselenahexaselenaphosphorins; triselenahexaselenaphosphorins; diselenahexaoxaselenins; triselenahexaoxaselenins; diselenahexadiselenins; and triselenahexadiselenins.

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Se Valence Stabilizer #16: Examples of 1,3-diselenoketones (diseleno-beta-ketonates), 1,3,5-triselenoketones, bis(1,3-diselenoketones), and poly(1,3-diselenoketones) (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: hexafluoropentanediselenone; 1,3-diphenyl-1,3-propanediselenone; selenobenzoylselenopinacolone; diselenocyclohexoxymethane; diphenylpentanetriseleenoate; tetramethylnonanetriseleenoate; hexafluoroheptanetriseleenoate; trifluoroheptanetriseleenoate; 1-(2-thienyl)-1,3-butanediselenone, 1-(2-naphthyl)-1,3-butanediselenone, and trifluoroselenoacetylselenocamphor.

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Se Valence Stabilizer #17: Examples of 1,1-diselenolates, bis(1,1-diselenolates), and poly(1,1-diselenolates) (Se-Se Bidentates and Se-Se Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: 1,1-dicyano-2,2-ethylene diselenolate; 1,1-dicarboalkoxy-2,2-ethylene diselenolate; 1,1-di(trifluoromethyl)-2,2-ethylene diselenolate; 1,1-di(pentafluorophenyl)-2,2-ethylene diselenolate; 1-pentamethylene-2,2-ethylene diselenolate; and 1-nitroethylene diselenolate.

Se Valence Stabilizer #18: Examples of diselenocarbamates, bis(diselenocarbamates), and poly(diselenocarbamates) (including N-hydroxydiselenocarbamates and N-

mercaptodiselenocarbamates) (Se-Se Bidentates, Se-Se Tridentates, and Se-Se Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: dimethyldiselenocarbamate; di(trifluorodimethyl)diselenocarbamate; diethyldiselenocarbamate; dipropyldiselenocarbamate; diisopropyldiselenocarbamate; dibutyldiselenocarbamate; ditertbutyldiselenocarbamate; dicyanamidodiselenocarbamate; azidoselenoformates; diphenyldiselenocarbamate; di(pentafluorophenyl)diselenocarbamate; dibenzylidiselecarbamate; dinaphthyldiselenocarbamate; dicyclohexyldiselenocarbamate; dinorbornyldiselenocarbamate; diadamantyldiselenocarbamate; pyrrolidinodiselenocarbamate; piperidinodiselenocarbamate; morpholinodiselenocarbamate; thiamorpholinodiselenocarbamate; 3-pyrrolinodiselenocarbamate; pyrrolodiselenocarbamate; oxazolodiselenocarbamate; isoxazolodiselenocarbamate; thiazolodiselenocarbamate; isothiazolodiselenocarbamate; indolodiselenocarbamate; carbazolodiselenocarbamate; pyrazolinodiselenocarbamate; imidazolinodiselenocarbamate; pyrazolodiselenocarbamate; imidazolodiselenocarbamate; indazolodiselenocarbamate; and triazolodiselenocarbamate.

Se Valence Stabilizer #19: Examples of triselenophosphoric acids (phosphorotriselenoic acids), bis(triselenophosphoric acids), poly(triselenophosphoric acids), and derivatives thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetridentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: triselenophosphoric acid, O-phenyltriselenophosphoric acid, O-benzyltriselenophosphoric acid, O-cyclohexyltriselenophosphoric acid, O-norbornyltriselenophosphoric acid, O,Se-

diphenyltriselenophosphoric acid, O,Se-dibenzyltriselenophosphoric acid, O,Se-dicyclohexyltriselenophosphoric acid, and O,Se-dinorbornyltriselenophosphoric acid.

Se Valence Stabilizer #20: Examples of diselenophosphoric acids (phosphorodiselenoic acids),

- 5 bis(diselenophosphoric acids), poly(diselenophosphoric acids), and derivatives thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: diselenophosphoric acid, O-phenyldiselenophosphoric acid, O-benzyltriselenophosphoric acid, O-cyclohexyldiselenophosphoric acid, O-norbornyldiselenophosphoric acid, O,O-
- 10 diphenyldiselenophosphoric acid, O,O-dibenzyltriselenophosphoric acid, O,O-dicyclohexyldiselenophosphoric acid, and O,O-dinorbornyldiselenophosphoric acid.

Se Valence Stabilizer #21: Examples of tetraselenophosphoric acids (phosphorotetraselenoic acids), bis(tetraselenophosphoric acids), poly(tetraselenophosphoric acids), and derivatives

- 15 thereof (Se-Se Bidentates, Se-Se Tridentates, Se-Se Tetracentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: tetraselenophosphoric acid, Se-phenyltetraselenophosphoric acid, Se-benzyltetraselenophosphoric acid, Se-cyclohexyltetraselenophosphoric acid, Se-norbornyltetraselenophosphoric acid, Se,Se-diphenyltetraselenophosphoric acid, Se,Se-
- 20 dibenzyltetraselenophosphoric acid, Se,Se-dicyclohexyltetraselenophosphoric acid, and Se,Se-dinorbornyltetraselenophosphoric acid.

Se Valence Stabilizer #22: Examples of diselenocarbonates, triselenocarbonates,

- bis(diselenocarbonates), and bis(triselenocarbonates), (Se-Se Bidentates and S-S Tetracentates)
- 25 that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: Se,Se-diethyldiselenocarbonate; Se,Se-diisopropyldiselenocarbonate; Se,Se-diphenyldiselenocarbonate; Se,Se-dibenzyltriselenocarbonate; Se,Se-dicyclohexyldiselenocarbonate; Se,Se-dinorbornyldiselenocarbonate; diethyltriselenocarbonate; diisopropyldiselenocarbonate; diphenyltriselenocarbonate; dibenzyltriselenocarbonate;
- 30 dicyclohexyltriselenocarbonate; and dinorbornyltriselenocarbonate.

Se Valence Stabilizer #23: Examples of selenocyanate ligands (Se monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: selenocyanate ($-\text{SeCN}$).

- 5 Se Valence Stabilizer #24: Examples of selenolates (Se monodentates) that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: selenophenol; and naphthaleneselenol.

- Miscellaneous Valence Stabilizer #1: Examples of diene, bicyclic and tricyclic hydrocarbon
10 ligands that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: cyclopentadiene; azulene; carotene; norbornane; and adamantane.

- Miscellaneous Valence Stabilizer #2: Examples of cyanide and related ligands that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to:
15 cyanide ($-\text{CN}$); and fulminate ($-\text{CNO}$).

- Miscellaneous Valence Stabilizer #3: Examples of carbonyl ligands that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: carbonyl ($-\text{CO}$); and carbon dioxide (CO_2) ligands.
20

Miscellaneous Valence Stabilizer #4: Examples of halogens that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: fluorine; chlorine; bromine; and iodine.

- 25 Miscellaneous Valence Stabilizer #5: Examples of hydroxo and oxo functionalities that meet the requirements for use as “narrow band” valence stabilizers for Ce^{+4} include, but are not limited to: water (H_2O); dioxygen (O_2); oxide (O^{2-}); hydroxide (OH^-); peroxy groups (O_2^{2-}); and superoxo groups (O_2^-).

30

2e) Mixed Inorganic/Organic Valence Stabilizers

Mixing organic and inorganic valence stabilizers in a rinsing or sealing solution will often result in a coating with poor corrosion-inhibiting properties because of cross interference.

Inorganic and organic valence stabilizers interact with the Ce^{+4} ion in different ways. For

5 example, inorganic valence stabilizers perform their function by forming a shell of octahedrally or icosahedrally coordinated anionic species around the captured Ce^{+4} ion. Therefore, the net charge of these inorganic valence stabilizer/ Ce^{+4} complexes is always negative. Organic species stabilize by the formation of a "hard bond" between the bonding atom in the stabilizer (e.g., nitrogen or oxygen) and the Ce^{+4} ion. The net charge of these complexes is often positive. If
10 these two very different types of stabilization ligands are combined, then the magnitude of the charge on the stabilized complex can be reduced significantly. The performance of organic or inorganic stabilized corrosion inhibitor complexes has been found to be directly related to the ability of the complex to form and sustain a thick electrostatic barrier layer. Additionally, a mixed stabilizer can have a poorly developed electrostatic field and a non-optimal packing
15 around the Ce^{+4} ion, resulting in a complex with less resistance to aqueous attack. Mixed organic/inorganic stabilized Ce^{+4} inhibitor species will usually perform more poorly than inhibitors that have exclusively organic or inorganic valence stabilizers for this reason.

2f) Valence Stabilizers for Tetravalent Praseodymium or Terbium

20 The PrIV and TbIV ions form very few stable complexes with inorganic or organic compounds. Examples of typical wide band inorganic ligands for PrIV or TbIV include periodates, tellurates, tungstates, molybdates, vanadates, carbonates, and phosphates. Under certain circumstances, narrow band inorganic ligands such as oxygen, fluorides, antimonates, iodates, and bromates may be acceptable. Examples of typical organic ligands for PrIV or TbIV
25 include dithiocarbamates, dithiolenes, dithiols, dithioketones, biguanides, oximes, Schiff bases, and some azo compounds. PrIV or TbIV may be used in the future with compounds not currently identified.

3) Oxidation Source

30 Oxidizers serve two important functions within the coatings enhanced through the use of the described rinses and seals: 1) they act in cooperation with the stabilizer to impede the flow of

ionic species through the coating, therefore minimizing charge transport, and 2) if a scratch is formed in the coating, these oxidizing species act to repair the breach by oxidizing the metal in the presence of water, and quickly reforming an oxide barrier. The effectiveness of the oxidizing species is a function of its individual oxidation-reduction potential, with more highly oxidized

5 species exhibiting greater corrosion protection.

In order to provide adequate oxidation potential in the rinse and seal solutions, especially if trivalent cerium, praseodymium, or terbium compounds are utilized as precursors, an oxidizing species is also included as a starting material. Additional amounts of oxidizer may be added to help control and maintain a desired amount of Ce^{+4} , Pr^{+4} , or Tb^{+4} in the rinse or seal solution by reoxidizing Ce^{+4} , Pr^{+4} , or Tb^{+4} that has been reduced. Because of the high potential of the redox reaction required to oxidize trivalent cerium, praseodymium, or terbium to tetravalent cerium, praseodymium, or terbium, strong oxidizers must be utilized for this purpose. These oxidizers may be gaseous, liquid, or solid in form. Solid oxidizers are preferable for this application in terms of handling and reagent measurement. Other starting materials (cerium, praseodymium, or terbium source, stabilizer source, fluoride source) will frequently also be solids. Liquid oxidizers may also be used, but handling and accurate process metering have proven difficult. Gaseous oxidizers may be the most effective and chemically efficient on a large scale, but are also the most problematic due to handling and venting concerns.

Examples of oxidizers suitable for the purpose of producing and maintaining the cerium, praseodymium, or terbium ion in the tetravalent charge state include, but are not restricted to: peroxides and peroxy compounds (including superoxides, persulfates, perborates, pernitrites, perphosphates, percarbonates, persilicates, peraluminates, pertitanates, perzirconates, permolybdates, pertungstates, pervanadates, and organic peroxyacid derivatives), ozone, hypochlorites, chlorates, perchlorates, hypobromites, chlorites, bromates, nitrates, nitrites, vanadates, iodates, permanganates, periodates, and dissolved oxygen. Both inorganic and organic derivatives of these compounds may be used. Typical oxidizers are peroxides, persulfates, perbenzoates, periodates, bromates, hypochlorites, and gaseous dissolved oxygen (including the oxygen content of air). In general, any inorganic, organic, or combination species that has an oxidation potential of +1.6 V or higher (at a pH of 1) will be capable of oxidizing trivalent cerium to the tetravalent oxidation state. The formation of tetravalent praseodymium or terbium requires higher oxidation potentials. In the presence of suitable valence stabilizer

compounds, tetravalent praseodymium or terbium can be formed from praseodymium or terbium solutions with an oxidation potential of +2.0 V or higher (at a pH of 1).

It is also possible to deposit trivalent cerium, praseodymium, or terbium into the pore via the rinse or seal solution, and then apply a second solution containing an oxidizer to oxidize the cerium, praseodymium, or terbium to the tetravalent oxidation state. This, however, is less preferred because the percentage of deposited cerium, praseodymium, or terbium that will be in the tetravalent state will be less than if it were oxidized prior to or during deposition.

In the rinse and seal solutions based on hexavalent chromium, oxidation sources termed “accelerators” are often added to speed up the pore-filling process. Because the application of an acid (i.e., a rinse or seal solution) to an electronegative metal will result in the formation of hydrogen gas, cathodic areas on exposed metal will be partially blocked from further coating formation. Oxidizers (“accelerators”) act to eliminate hydrogen gas formation, thereby minimizing its barrier effect, and hence accelerating the overall deposition rate. It is for this reason that it is desirable to have oxidizers in the initial rinsing or sealing solution based on cerium, praseodymium, or terbium.

Oxidation of the cerium, praseodymium, or terbium to the tetravalent state may also be achieved in the rinse or seal solution or in deposited trivalent cerium, praseodymium, or terbium complexes through electrolytic means. In many instances, however, this approach will not be economically feasible due to the large energy costs associated with electrolytic oxidation. This is especially true of rinse and seal solutions to be used for phosphate or black oxide coatings. For these types of coatings, chemical oxidation, such as that described above, currently offers the lowest-cost means to achieve oxidation of the cerium, praseodymium, or terbium to the tetravalent state.

However, for anodic coatings and processes, this electrolytic alternative is a very viable option due to the electrolytic application of the first (oxide barrier layer) coating. In fact, electrolytic processes are often used for the coloring of anodic coatings. However, formation of tetravalent cerium, praseodymium, or terbium complexes in the pores of the anodic coating will differ significantly from the current state-of-the-art anodic coloring processes. In the current state-of-the-art anodic coloring processes achieved by electrolytic means, the bare uncoated work piece to be anodized is first connected to an electrolytic cell as the anode. Once a potential is applied, the metal associated with the work piece is oxidized on the surface, thereby forming an

oxide/hydroxide barrier layer. In the second step (electrolytic coloring) of the state-of-the-art, the work piece is positioned so that it is the cathode of the electrolytic cell, resulting in reduction on the surface of the work piece. (Transfer of the work piece to a cathode is usually achieved by reversing the electric biases of the cell, although manual repositioning is also a possibility.) In this way, the metals associated with the second solution are reduced either to the elemental state or to sulfides within the pores of the anodic coating, resulting in coloring.

In order to oxidize trivalent cerium, praseodymium, or terbium to the tetravalent state in the solution or the coating, a similar procedure as the state-of-the-art is followed, except that in the application of the second solution, the work piece should remain as the anode. Therefore, following formation of the oxide barrier film in the anodization process, it is not necessary to reverse the bias or manually transfer the work piece so that it is the cathode in the electrolytic cell. Formation of tetravalent cerium, praseodymium, or terbium can be achieved with the work piece still connected as the anode. In this way, it is necessary only to change the solution from one used for anodization (e.g., sulfuric acid anodization) to a composition such as that described in this invention to achieve superior corrosion protection. Coloring of the anodic coating can also be achieved using this approach, because of the wide range of colors achievable with some tetravalent cerium, praseodymium, or terbium/valence stabilizer complexes.

4) Preparative Agent Source

The deposition of tetravalent cerium, praseodymium, or terbium/valence stabilizer complexes within the pores of anodic, phosphate, or "black oxide" coatings is enhanced if some of the existing barrier layer, particularly in the vicinity of the pores, is dissolved. Therefore it is optionally desirable to remove the existing barrier layer to achieve high-quality coatings resulting from rinsing and sealing. A preparative agent is any material that removes (dissolves and breaks up) preexisting coating materials. The hexavalent chromium formulations term these materials "activators" or "surface etchants." Because the existing barrier layer material at the margins of the pores will be slightly more disordered than in the bulk of the existing film, the preparative agent will preferentially attack the pore wall material. This in turn locally raises the pH in the vicinity of the pore, thereby further facilitating precipitation of tetravalent cerium, praseodymium, or terbium/valence stabilizer inhibitor complexes.

Fluoride acids and salts work especially well as preparative agents in rinse and seal compositions. The complex fluoride anions hexafluorozirconate (ZrF_6^{-2}) and hexafluorotitanate (TiF_6^{-2}) are superior fluoride sources for this application. Hexafluorosilicates (SiF_6^{-2}) can be used, but they result in a reduced level of subsequent corrosion protection. The potassium, lithium, sodium, or ammonium salts of these anions work especially well for this application, with potassium performing the best.

Other complex fluorides, including, but not restricted to, fluoroaluminates (e.g., AlF_6^{-3} or AlF_4^{-1}), fluoroborates (e.g., BF_4^{-1}), fluorogallates (e.g., GaF_4^{-1}), fluoroindates (e.g., InF_4^{-1}), fluorogermanates (e.g., GeF_6^{-2}), fluorostannates (e.g., SnF_6^{-2}), fluorophosphates (e.g., PF_6^{-1}), fluoroarsenates (e.g., AsF_6^{-1}), fluoroantimonates (e.g., SbF_6^{-1}), fluorobismuthates (e.g., BiF_6^{-1}), fluorosulfates (e.g., SF_6^{-2}), fluoroselenates (e.g., SeF_6^{-2}), fluorotellurates (e.g., TeF_6^{-2} or TeOF_5^{-1}), fluorocuprates (e.g., CuF_3^{-1} or CuF_4^{-2}), fluoroargentates (e.g., AgF_3^{-1} or AgF_4^{-2}), fluorozincates (e.g., ZnF_4^{-2}), fluorohafnates (e.g., HfF_6^{-2}), fluorovanadates (e.g., VF_7^{-2}), fluoroniobates (e.g., NbF_7^{-2}), fluorotantalates (e.g., TaF_7^{-2}), fluoromolybdates (e.g., MoF_6^{-3}), fluorotungstates (e.g., WF_6^{-1}), fluoroyttrates (e.g., YF_6^{-3}), fluorolanthanates (e.g., LaF_6^{-3}), fluorocerates (e.g., CeF_6^{-3} or CeF_6^{-2}), fluoromanganates (e.g., MnF_6^{-2}), fluoroferrates (e.g., FeF_6^{-3}), fluoronickelates (e.g., NiF_6^{-2}), and fluorocobaltates (e.g., CoF_6^{-2}) are also suitable fluoride sources, but these offer even less corrosion protection than hexafluorosilicates. Water-soluble potassium, sodium, lithium, or ammonium salts of these anions are typical.

Simple inorganic fluorides such as potassium fluoride (KF), potassium hydrogen fluoride (KHF_2), sodium fluoride (NaF), sodium hydrogen fluoride (NaHF_2), lithium fluoride (LiF), lithium hydrogen fluoride (LiHF_2), ammonium fluoride (NH_4F), ammonium hydrogen fluoride (NH_4HF_2), and hydrofluoric acid solutions (HF) can also be used as a fluoride source. By analogy, organic compounds that readily release fluoride ions will also serve as adequate fluoride sources.

Other halide species, such as chlorides (Cl^-), bromides (Br^-), and iodides (I^-) can also function as preparative agents, although their efficiency in dissolving the existing barrier film will not be as great as the fluorides. Inorganic or organic compounds that release chloride, bromide, or iodide anions can function as preparative agents, as can a number of complex chlorides and bromides that are similar to those described above for the fluorides. By analogy, complex hexachlorozirconates (ZrCl_6^{-2}), hexachlorotitanates (TiCl_6^{-2}), and hexachlorosilicates

(SiCl_6^{2-}) should function better than other chloride sources, and analogous complex bromide and iodide sources will function better than other bromides and iodides.

Acidic species, such as nitric acid, sulfuric acid, phosphoric acid, pyrophosphoric acid, hydrochloric acid, perchloric acid, hydrobromic acid, hydriodic acid, iodic acid, periodic acid, disulfuric acid, selenic acid, telluric acid, polyphosphoric acid, cyclophosphoric acid, phytic acid, boric acid, carboxylic acids, phosphonic acids, and sulfonic acids can also function as preparative agents. Of these, nitric acid is the most useful as a preparative agent.

Acidic species based on metal salts that exhibit a pH below 7 when placed into solution can also be used as preparative agents. The advantage in the use of these species as preparative agents is that they can help eliminate the need for fluoride species, which are regulated in some locations. Metal salts of titanium, zirconium, niobium, tantalum, molybdenum, tungsten, vanadium, aluminum, silicon, tin, antimony, bismuth, tellurium, yttrium, and lanthanum are especially useful for this process. Halides, nitrates, sulfates, perchlorates, and carboxylates of these metals, including double salts with alkali metals or ammonium are most suited as acidic metal salts due to their water solubility.

Although it is less desirable, hydroxides can also function as preparative agents. For example, under high pH conditions zinc and aluminum are known to dissolve in water, through the formation of zincate or aluminate anions. The use of hydroxides such as sodium, potassium, lithium, or ammonium derivatives will result in this pH rise.

If used, the concentration of fluoride preparative agent should not exceed a value wherein the majority of the existing barrier layer should begin to be dissolved in the rinse or seal composition. This will result in reduced corrosion protection of the barrier film-tetravalent cerium, praseodymium, or terbium/valence stabilizer system. A maximum recommended concentration of fluoride for these rinses and seals is typically 0.5 M F^- . For some specialized applications, such as rinsing or sealing refractory metals such as titanium, zirconium, niobium, and tantalum, or for treating tenacious or thick oxides of magnesium or aluminum, fluoride concentrations as high as 5.0 M F^- may be allowable.

5) - Additional Solubility Control Agents

One of the roles of the valence stabilizer is to allow for the formation of a tetravalent cerium, praseodymium, or terbium complex that has a specific solubility range. The anions or

cations present in the rinse or sealing solution may be sufficient to form a Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -containing compound within the rinsed or sealed coating that exhibits the desired solubility characteristics. However, additional solubility control may be desirable to optimize the performance of the tetravalent cerium-, praseodymium-, or terbium-valence stabilizer complex.

- 5 The use of an additional solubility control agent is optional, not required.

Both the organic and inorganic valence stabilizers described above may need some kind of additional solubility control that can be in the form of either inorganic or organic compounds. Solubility control agents should be selected to match the cationic or anionic modifiers with individual Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer combinations. Some cations or anions may
10 work to optimize one Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complex, but this does not necessarily mean they will optimize the solubility of a different complex.

The initial rinsing or sealing of a barrier film may produce Ce^{+4} -, Pr^{+4} -, or Tb^{+4} compounds with solubilities greater than optimal. A post-deposition treatment can be applied to the coating as a remedial treatment or as a desired process step. Additional solubility control agents applied
15 to a work piece can enhance the Ce^{+4} -, Pr^{+4} -, or Tb^{+4} content of the coating by forming more insoluble compounds in place. Application of a second solution after the initial rinse or seal process has been found to result in enhanced solubility control of Ce^{+4} -, Pr^{+4} -, or Tb^{+4} in many formulations.

Additional solubility control agents are typically applied as a second solution. Otherwise,
20 these cations or anions would begin to precipitate cerium-, praseodymium-, or terbium-containing compounds in the rinse or seal solution, depleting it of cerium, praseodymium, or terbium prior to treating the work piece. In general, fine-tuning of solubility by cationic species is typical for Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -stabilizer combinations when an inorganic valence stabilizer is used, and by anionic species when an organic valence stabilizer is used.

25 The need for an additional solubility control agent may be illustrated for the situation where molybdate is used as a valence stabilizer for a Ce^{+4} seal solution. Cationic species are necessary to deposit a Ce^{+4} /molybdate compound within the coating (the net charge on a Ce^{+4} /heteropolymolybdate anion may either be -2, -4, or -8). The cationic species needed to balance the charge and form a compound is usually supplied from cations already present in the
30 rinse solution and/or by cations being pulled into the solution from the work piece. However, if the Ce^{+4} /molybdate complex composed of the available cations has a much greater solubility

than desired, then additional solubility control agents can be employed. The differences in effectiveness of a specific rinse or seal formulation upon different substrate materials (e.g., zinc, iron, magnesium) is likely a reflection of the influence that the composition of the alloy itself has upon the solubility of the deposited inhibitor species. Similarly, anions present in a rinse or seal solution or source material will be incorporated in a Ce^{+4} compound that requires a negative charge balance. This is frequently observed with Ce^{+4} /organic valence stabilizer combinations.

The use of solubility control agents to enhance corrosion protection has also been demonstrated in the state-of-the-art hexavalent chromium solutions. For example, the sealing of anodic coatings with hexavalent chromium (resulting in the formation of somewhat soluble hydrated aluminum chromate) followed by rinsing with a zinc solution (resulting in the deposition of less-soluble zinc chromate in the pores) has been shown to increase the corrosion resistance for this system. However, hexavalent chromium rinsing of phosphate coatings over electrogalvanized steel does not require additional solubility control because of the initial formation of zinc chromate in the pores.

Additional solubility control can be achieved through the use of nontoxic inorganic cations which include, but are not limited to: H^+ , Li^+ , Na^+ , K^+ , Rb^+ , Cs^+ , NH_4^+ , Mg^{+2} , Ca^{+2} , Sr^{+2} , Y^{+3} , La^{+3} , Ce^{+3} , Ce^{+4} , Nd^{+3} , Pr^{+3} , Sc^{+3} , Sm^{+3} , Eu^{+3} , Eu^{+2} , Gd^{+3} , Tb^{+3} , Dy^{+3} , Ho^{+3} , Er^{+3} , Tm^{+3} , Yb^{+3} , Lu^{+3} , Ti^{+4} , Zr^{+4} , Ti^{+3} , Hf^{+4} , Nb^{+5} , Ta^{+5} , Nb^{+4} , Ta^{+4} , Mo^{+6} , W^{+6} , Mo^{+5} , W^{+5} , Mo^{+4} , W^{+4} , Mn^{+2} , Mn^{+3} , Mn^{+4} , Fe^{+2} , Fe^{+3} , Co^{+2} , Co^{+3} , Ru^{+2} , Ru^{+3} , Ru^{+4} , Rh^{+3} , Ir^{+3} , Rh^{+2} , Ir^{+2} , Pd^{+4} , Pt^{+4} , Pd^{+2} , Pt^{+2} , Cu^+ , Cu^{+2} , Cu^{+3} , Ag^+ , Ag^{+2} , Ag^{+3} , Au^+ , Au^{+2} , Au^{+3} , Zn^{+2} , Al^{+3} , Ga^{+3} , Ga^+ , In^{+3} , In^+ , Ge^{+4} , Ge^{+2} , Sn^{+2} , Sn^{+4} , Sb^{+3} , Sb^{+5} , Bi^{+3} , and Bi^{+5} . Any water-soluble compound that contains these cations can be used for this purpose. Nitrates, chlorides, bromides, and perchlorates of these cations offer inexpensive water-soluble precursors, although many other water-soluble precursors exist.

Cationic solubility control may also be achieved through the use of non-toxic organic cations that include, but are not limited to: quaternary ammonium compounds (NR_4^+ , where R can be any combination of alkyl, aromatic, or acyclic organic substituents, such as the methyltriethylammonium ion); organics that contain at least one N^+ site (such as pyridinium or thiazolium cations); organics that contain at least one phosphonium site (P^+ , such as the benzyltriphenylphosphonium ion); organics that contain at least one stibonium site (Sb^+ , such as the tetraphenylstibonium ion); organics that contain at least one oxonium site (O^+ , such as

pyrylium cations); organics that contain at least one sulfonium site (S^+ , such as the triphenylsulfonium ion); and organics that contain at least one iodonium site (I^+ , such as the diphenyliodonium ion).

The quaternary ammonium compounds, organics containing at least one N^+ site, and
5 organics containing at least one oxonium site are the most important of these classifications because of the very large number of stable cations that are available. Water-soluble precursors for these organic cations are desirable in order to maximize the amount of material available in the appropriate rinse or seal solution. Fluorides, chlorides, and bromides offer the most water-soluble precursors for these organic cations, although lower molecular weight nitrates and
10 perchlorates of these cations (e.g., tetramethylammonium) are also acceptable water-soluble precursors. Nitrates and perchlorates of larger (higher molecular weight) organic cations are not acceptable as precursors because of their low water solubility.

Although it is less desirable, toxic inorganic or organic cations can be used as additional solubility control agents. Examples of toxic inorganic cations that can be used include, but are
15 not limited to: Be^{+2} , Ba^{+2} , V^{+5} , V^{+4} , V^{+3} , Cr^{+3} , Ni^{+2} , Ni^{+4} , Os^{+4} , Cd^{+2} , Hg^{+1} , Hg^{+2} , Tl^{+} , Tl^{+3} , As^{+3} , As^{+5} , Pb^{+2} , and Pb^{+4} . Examples of toxic organic cations include, but are not limited to: organic compounds that contain at least one arsonium site (As^+ , an example being the tetraphenylarsonium ion) and organic compounds that contain at least one selenonium site (Se^+ ,
an example being the triphenylselenonium ion). Use of these materials for additional solubility
20 control may be appropriate in some specific instances where the toxicity of the coating baths is of limited importance to the operator. Water-soluble precursors for these toxic cations are typically used in order to maximize the amount of available cation for solubility control. In general, the nitrates, fluorides, chlorides, bromides, and perchlorates of these cations offer the highest water solubility.

25 Additional solubility control can also be achieved through the use of nontoxic inorganic anions, especially for Ce^{+4} , Pr^{+4} , or Tb^{+4} /organic valence stabilizer combinations. Water-soluble precursors for these inorganic anions are desirable in order to maximize the amount of material available in the appropriate rinse or seal solution. These include, but are not limited to: fluorotitanates, chlorotitanates, fluorozirconates, chlorozirconates, fluoroniobates,
30 chloroniobates, fluorotantalates, chlorotantalates, molybdates, tungstates, permanganates, fluoromanganates, chloromanganates, fluoroferrates, chloroferrates, fluorocobaltates,

chlorocobaltates, fluorozincates, chlorozincates, borates, fluoroborates, fluoroaluminates, chloroaluminates, carbonates, silicates, fluorosilicates, fluorostannates, nitrates, nitrites, azides, phosphates, phosphites, phosphonates, phosphinites, thiophosphates, thiophosphites, thiophosphonates, thiophosphinites, fluorophosphates, fluoroantimonates, chloroantimonates, sulfates, sulfites, sulfonates, thiosulfates, dithionites, dithionates, fluorosulfates, tellurates, fluorides, chlorides, chlorates, perchlorates, bromides, bromates, iodides, iodates, periodates, and heteropolyanions (e.g., heteropolymolybdates, silicomolybdates, etc.).

Additional solubility control can also be achieved through the use of an almost unlimited number of non-toxic organic anions (e.g., organics with different carboxylates or acid groups).

- 10 Examples include, but are not limited to: ferricyanides; ferrocyanides; cyanocobaltates; cyanocuprates; cyanomanganates; cyanates; cyanatoferrates; cyanatocobaltates; cyanatocuprates; cyanatomanganates; thiocyanates; thiocyanatoferrates; thiocyanatocobaltates; thiocyanatocuprates; thiocyanatomanganates; cyanamides; cyanamidoferrates; cyanamidocobaltates; cyanamidocuprates; cyanamidomanganates; nitritoferrates;
- 15 nitritocobaltates; azides; (thio)carboxylates, di(thio)carboxylates, tri(thio)carboxylates, or tetra(thio)carboxylates [useful representatives including, but not limited to, acetic acid, benzoic acid, succinic acid, fumaric acid, salicylic acid, lactic acid, tartaric acid, antimonyl tartrates, cinnamic acid, adipic acid, phthalic acid, terephthalic acid, citric acid, ascorbic acid, malic acid, malonic acid, oxalic acid, stearic acid, gallic acid, naphthenic acid, camphoric acid, nitrosalicylic
- 20 acid, aminosalicylic acid, acetylsalicylic acid, sulfosalicylic acid, nitrobenzoic acid, perfluoroC₂₋₁₆carboxylic acids, trinitrobenzoic acid, chlorobenzoic acid, anisic acid, iodobenzoic acid, anthranilic acid, mandelic acid, toluic acid, nicotinic acid, isonicotinic acid, pyrazolecarboxylic acid, picrolonic acid, quinaldic acid, diphenic acid, benzoquinaldic acid, quinolinecarboxylic acid, isoquinolinecarboxylic acid, triazinecarboxylic acid, (thio)carbonic acids, (thio)carbamic
- 25 acids, trimethylhexylic acid, tetrafluorophthalic acid, ethylenediaminetetraacetic acid, toluoylpropionic acid, lactobionic acid, octylthiopropionate, lipoic acid, methylbenzoylpropionic acid, anthracenesuccinic acid, benzothiazolecarboxylic acid, phenylacetic acid, glycolic acid, thioglycolic acid, benzothiazolylthiosuccinic acid, benzothiazolylthiopropionic acid, phenylanthranilic acid, furancarboxylic acid, nitrofuroic acid, phosphonobutanetricarboxylic
- 30 acid, benzothiazolylthiosuccinic acid, N-phosphonomethylglycine, cresoxyacetic acid, aminobutyric acid, alanine, asparagine, cysteine, glutamine, glycine, leucine, methionine,

phenylalanine, proline, serine, threonine, tryptophan, tyrosine, valine, glutamic acid, aspartic acid, arginine, histidine, lysine, trihydroxyglutaric acid, phenoxyacetic acid, hydroxynaphthoic acid, phenylbutyric acid, hydroxyphosphonoacetic acid, tropic acid, aminophenylpropionic acid, dihydrocinnamic acid, hydroxycinnamic acid, cinchomeric acid, aurintricarboxylic acid,

5 benzotriazolecarboxylic acid, hydroxyphosphonoacetic acid, cyanuric acid, barbituric acid, violuric acid, diphenylvioluric acid, dilituric acid, thiobarbituric acid, cresotic acid, trimethylhexylic acid, nitrilotriacetic acid, N,N'-terephthaloylbis(aminocaproic acid), ethyleneglycolbis(aminoethylether)tetraacetic acid, diethylenetriaminepentaacetic acid, 2-phosphonobutanetricarboxylic acid, N,N'-bis(2-hydroxysuccinyl)ethylenediamine, nicotinic

10 acid, naptalam, nitrobenzoic acid, nonylphenoxyacetic acid, and olsalazine]; (thio)phenolates, di(thio)phenolates, tri(thio)phenolates, or tetra(thio)phenolates [useful representatives including, but not limited to, pyrocatechol, resorcinol, picric acid, styphnic acid, pyrogallol, purpurin, purpurogallin, benzopurpurin, gallein, thiophenol, rhodizonic acid, kojic acid, chromotropic acid, carminic acid, fluorescein, tannic acid, and humic acid]; (thio)phosphonates,

15 di(thio)phosphonates, or tri(thio)phosphonates [useful representatives including, but not limited to, diethylphosphonic acid, diphenylphosphonic acid, nitrophenylphosphonic acid, perfluoroC₂₋₁₆phosphonic acids, benzenephosphonic acid, phytic acid, hydroxyethylidenebisphosphonic acid, nitrilotrimethylenephosphonic acid, aminomethylenephosphonic acid, etidronic acid, ethylphosphonic acid, chloroethylphosphonic acid, ethylenediaminetetramethylenephosphonic

20 acid, laurylhydroxydiphosphonic acid, methylaminodimethylenephosphonic acid, alkyl(aryl)diphosphonic acids, N-cetylaminooethanediphosphonic acid, carboxyhydroxymethylphosphonic acid (hpa), oxyethylidenediphosphonic acid, polycaproadidophosphonates, phenylethanetriphosphonic acid, oxidronic acid, and pamidronic acid]; (thio)phosphonamides, di(thio)phosphonamides, or tri(thio)phosphonamides [useful

25 representatives including, but not limited to, phosphoramidic acid, phosphordiamidic acid (diamidophosphonic acid), and phosphoramidothioic acid]; amino(thio)phosphonates, diamino(thio)phosphonates, or triamino(thio)phosphonates; imino(thio)phosphonates or diimino(thio)phosphonates; (thio)sulfonates, di(thio)sulfonates, or tri(thio)sulfonates [useful representatives including, but not limited to, methanesulfonic acid, benzenesulfonic acid,

30 aminobenzenesulfonic acid (sulfanilic acid), nitrobenzenesulfonic acid, phenylsulfonic acid, naphthalenesulfonic acid, nitronaphthalenesulfonic acid, oxinesulfonic acid, alizarinsulfonic

acid, benzidinesulfonic acid, flavianic acid, camphorsulfonic acid, diiodophenolsulfonic acid (soziodol), 8-hydroxyquinoline-5-sulfonic acid, 7-nitro-8-hydroxyquinoline-5-sulfonic acid, benzotriazolesulfonic acid, bis(trifluoromethyl)benzenesulfonic acid, diiododihydroxybenzophenonesulfonic acid, p-amino-p'-ethoxydiphenylamine-o-sulfonic acid,

5 1-amino-2-naphthol-4-sulfonic acid, 1,2-diaminoanthraquinone-3-sulfonic acid, 1,5-dinitro-2-naphthol-7-sulfonic acid, perfluoroC₂₋₁₆sulfonic acids, benzenedisulfonic acid, phenyldisulfonic acid, naphthalenedisulfonic acid, 3,6-naphtholdisulfonic acid, indigodisulfonic acid, benzidinedisulfonic acid, carboxyiodobenzenesulfonic acids, N-benzeneaminomethanesulfonic acid (ams), amido-G-acid, amido-R-acid, naphthalene(di)sulfonic acid (Armstrong's acid),

10 amsonic acid, Badische acid, camphorsulfonic acid, chrysophenine, Cassella's acid, chromotropic acid, Cleve's acid, croceic acid, anthracenesulfonic acid, hydroxyquinolinesulfonic acid, hydrazinobenzenesulfonic acid, indigo carmine, indoxyl, isatinsulfonic acid, indican, lignosulfonic acid, metanil yellow, metanilic acid, naphthoquinonesulfonic acid, Nuclear Fast Red, naphthol(di)sulfonic acid, naphthylamine(di)sulfonic acid, Orange I, orthanilic acid,

15 phenol(di)sulfonic acid, methylenedinaphthalenesulfonic acid, methyl orange, and piperazinediethanesulfonic acid (pipes)]; (thio)sulfonamides, di(thio)sulfonamides, or tri(thio)sulfonamides; amino(thio)sulfonates, diamino(thio)sulfonates, or triamino(thio)sulfonates; imino(thio)sulfonates (including sulfamates) or diimino(thio)sulfonates (including disulfamates) [useful representatives including, but not limited to, methylsulfamic acid and phenylsulfamic acid]; (thio)borates, di(thio)borates, or (thio)boronates [useful

20 representatives including, but not limited to, phenylboric acid and borotartaric acid]; organic silicates; and stibonates [useful representatives including, but not limited to, antimonyl tartrate and benzenestibonic acid]. Water-soluble precursors for these organic anions are desirable to maximize the amount available in the appropriate rinse or seal solution.

25 Finally, toxic inorganic or organic anions can be used as additional solubility control agents, although this is less desirable. Examples of toxic inorganic anions include, but are not limited to: arsenates, arsenites, fluoroarsenates, chloroarsenates, selenates, selenites, fluorothallates, chlorothallates, iodomercury anions (e.g., Nessler's reagent), thiocyanatomercury anions (Behren's reagent), chloromercurates, bromomercurates, osmates, fluoronickelates,

30 chromates, Reinecke's salt, and vanadates. Examples of toxic organic anions include cyanides; cyanochromates; cyanonickelates; cyanatochromates; cyanatonickelates; thiocyanatochromates;

thiocyanatonickelates; cyanamidochromates; cyanamidonickelates; nitritonickelates; arsonates, diarsonates, or triarsonates [useful representatives including, but not limited to, propylarsonic acid, phenylarsonic acid, hydroxyphenylarsonic acid, benzenearsonic acid, methylbenzenearsonic acid, hydroxybenzenearsonic acid, and nitrobenzenearsonic acid]; and

- 5 selenates, diselenates, or triselenates. These materials may be used in some specific instances for additional solubility control where coating bath toxicity is of limited importance. Water-soluble precursors for these anions are helpful in maximizing the amount of available anion for solubility control. The alkali or ammonium species of these anions typically offer the greatest water solubility.

10

6) Agents to Increase Lubricious Character of Coating

Iron and manganese phosphate coatings, as well as black oxide coatings, are used predominantly to provide a solid lubricant between two (or more) wear surfaces. A chrome rinse of these coatings can affect the tribological (lubricious) characteristics of the coating.

- 15 Specifically, materials that exhibit low coefficients of friction, or that result in the formation of materials with low coefficients of friction, can be added to the rinse solution to increase the lubriciousness of the rinsed coating. Examples of these include fine particulate or dissolved molybdenum disulfide, graphite, fluorinated hydrocarbons, polymers, or soft metals such as tin, indium, or silver.

20

7) Agents to Increase Color-Fastness of Coating

Rinsed or sealed coatings that are to be used for architectural or adornment applications will frequently be colored to improve the aesthetic nature of the work piece. Long-term exposure to high energy wavelengths (i.e., the ultraviolet wavelengths of sunlight) may fade or

- 25 dim the color of the coated work piece. The rinse or seal solution may include agents that improve the color-fastness of the coating. Typically, these are termed "UV blockers" in the paint and coatings literature. Active UV blockers are typically dark in color and function by absorbing nearly all of the light energy. Passive UV blockers are light in color and function by reflecting back nearly all of the light energy. Examples of active UV blockers include, but are not limited to, carbon black, graphite, or phthalocyanines. Examples of passive UV blockers include, but
- 30

are not limited to, titanium oxide, tin oxide, lead oxide, silicon oxide, silicates, or aluminosilicates, or combinations thereof.

The degree of color-fastness desired is strongly dependant upon the end use of the treated work piece. For example, metal pieces that have been phosphated or treated to obtain a black oxide coating often have lower ornamental requirements and, therefore, the requirements of the rinsing or sealing solutions are lower. Many anodized coatings, however, must meet very high ornamental requirements (especially for anodized aluminum), and the sealing solution must therefore meet these requirements. Even with anodized aluminum, the end use will dictate the degree of care required of the sealing solution. Thus, for parts that will only be exposed to interior light, a much wider selection of cerium, praseodymium, or terbium/valence stabilizer combinations will meet the ornamental requirements. For parts that will be exposed intermittently to UV light, as in automotive trim components, the choice of cerium, praseodymium, or terbium/valence stabilizer combinations is narrowed. Finally, work pieces that will be exposed to UV light on a continuous basis, such as architectural components, can only be treated with a limited number of cerium, praseodymium, or terbium/valence stabilizer combinations while still meeting the ornamental requirements.

The rinse or seal solution may also include wetting agents, such as nonionic surfactants at a concentration of, for example, 5g/L, as well as agents that prevent smudging to improve the color-fastness of the coating. These agents are particularly useful on powdery coatings and can include, but are not limited to, phosphoric acid, metaphosphates, orthophosphates, pyrophosphates, polyphosphates, or combinations thereof.

The color fastness of the treated coating will also be dependent upon the valence stabilizer. For example, the stability of the valence stabilizer or cerium, praseodymium, or terbium/valence stabilizer complex to UV light; the concentration of the valence stabilizer in the sealing bath; and the degree of penetration into the coating all can affect color fastness.

8) Agents to Add Color to the Formed Coating

It is desirable that coatings placed directly onto metal work pieces be colored so as to provide a metric of coating thickness, to identify uncoated areas, or even for aesthetic purposes. Rare earth compounds often exhibit no color in the coating, or result in very pale colored coatings. For this reason, it may optionally be advantageous to add a solvent-soluble (typically

water-soluble) colorant to the conversion coating solution. Dye chemicals such as vat dyes (i.e., indigo or anthraquinone), mordant and lake dyes (i.e., alizarin), direct dyes (i.e., mauve), disperse dyes (i.e., quinones), azo dyes, triazene dyes, triphenylmethane dyes (i.e., malachite green), azine dyes (i.e., methylene blue), formazan dyes, phthalocyanine dyes, Schiff Base dyes, 5 or naturally-occurring dyes (such as anthocyanins, carotenoids, quinines, melanins, ommochromes, pterins, porphyrins, and indigoids), or combinations thereof, can be used for this purpose. Inorganic pigments are also acceptable.

A) SOLUTION COMPOSITION AND PREPARATION

10 Additional important process considerations include chemical concentrations, pH of the rinse or seal solution, redox potential of the rinse or seal solution, application temperature, and contact time.

1) Solvents

15 Water is a typical solvent for these rinse or seal solutions due to its availability and low cost. Other solvents or combinations of water with other solvents (such as alcohols, ketones, etc.) may also be used if desired. However, these processes will be more costly than those using water exclusively. For sealing anodized aluminum, very high purity water is typically employed, and the concentrations of chloride, fluoride, sulfate, phosphate, and silicate should be minimized.

20

2) Cerium, Praseodymium, or Terbium Concentrations

The maximum concentration of the cerium, praseodymium, or terbium source depends upon the solubility of the specific cerium, praseodymium, or terbium source used. Any concentration exceeding this precursor solubility will result in undissolved solid material that 25 will not be incorporated into the rinse or seal solution. Therefore, the solubility of the cerium, praseodymium, or terbium sources in water at or near ambient temperature (25°C) can be used as representative maximum concentrations of the cerium, praseodymium, or terbium source that is added. Since the solubility of virtually all materials in water increases with temperature, more cerium, praseodymium, or terbium can be added to the rinse or seal solution if the temperature of 30 the bath is increased from ambient. However, cooling of these rinse or seal solutions with higher cerium, praseodymium, or terbium precursor concentrations will result in the precipitation of

solid cerium, praseodymium, or terbium compounds, with no guarantee that they could be resolubilized if the water is again heated (due to evaporation).

Acidic pHs will typically increase the solubility of many inorganic materials, thereby increasing the concentration of cerium, praseodymium, or terbium available in solution. A

- 5 general estimate of the maximum concentration of cerium, praseodymium, or terbium in the rinse or seal solution at ambient temperature can be determined from the solubilities of some of the more desirable cerium or praseodymium sources listed in Table 4. The solubility of terbium sources is often comparable to praseodymium sources.

10

Table 4

Solubilities of Some Cerium and Praseodymium Sources under Ambient Conditions
[Maximum Concentration of Cerium or Praseodymium in Solution]
(at or near 25°C and at or near pH 7)

Cerium or Praseodymium Source	Solubility in Water (mole/L)
Cerium (III) nitrate	1.5×10^0
Cerium (III) sulfate	1.2×10^{-1}
Cerium (III) perchlorate	2.0×10^0
Cerium (III) chloride	4.1×10^0
Cerium (III) bromide	1.0×10^0
Cerium (III) iodide	1.0×10^{-1}
Cerium (III) bromate	1.0×10^0
Cerium (III) formate	1.3×10^{-2}
Cerium (III) acetate	6.6×10^{-1}
Cerium (III) propionate	4.6×10^{-1}
Cerium (III) butyrate	7.7×10^{-2}
Cerium (III) dimethylphosphate	7.6×10^{-1}
Ammonium cerium (III) nitrate	5.7×10^0
Magnesium cerium (III) nitrate	4.3×10^{-1}
Ammonium cerium (III) sulfate	7.0×10^{-2}
Cerium (IV) chloride	1.0×10^0
Cerium (IV) perchlorate	1.0×10^0

Cerium (IV) sulfate	5.0×10^{-1}
Cerium (IV) nitrate	1.0×10^0
Cerium (IV) acetate	5.0×10^{-1}
Ammonium cerium (IV) nitrate	2.6×10^0
Ammonium cerium (IV) sulfate	5.0×10^{-1}
Praseodymium (III) nitrate	1.4×10^0
Praseodymium (III) sulfate	3.1×10^{-1}
Praseodymium (III) perchlorate	2.2×10^0
Praseodymium (III) chloride	8.9×10^0
Praseodymium (III) bromide	1.0×10^{-1}
Praseodymium (III) iodide	1.0×10^0
Praseodymium (III) bromate	2.9×10^0
Praseodymium (III) acetate	6.3×10^{-1}
Magnesium praseodymium (III) nitrate	4.1×10^{-1}

The depletion of cerium, praseodymium, or terbium from the coating solution below an acceptable level is a function of the amount of metal surface area being coated prior to regeneration of the bath. A coating applied to a very large surface area may deplete the solution to the point that subsequent solution applications no longer form effective coatings. Less cerium, praseodymium, or terbium will be removed from the rinse or seal solution when treating a smaller surface area of metal, so more work pieces can be treated from the same solution.

The corrosion-inhibiting cerium, praseodymium, or terbium compounds formed on the surface of the metal exhibit solubilities ranging from approximately 5×10^{-2} to 5×10^{-5} moles/liter of cerium, praseodymium, or terbium in water. Coating solutions with cerium, praseodymium, or terbium concentrations much less than these concentrations may: 1) withdraw cerium or praseodymium from the formed coating in order to attempt to reach an equilibrium, or 2) may produce an incomplete, poorly formed oxide film. Intentionally exhausted (depleted) rinse or seal solutions have been observed to degrade a coated surface and return cerium, praseodymium, or terbium to the rinse or seal solution. The lowest concentration of cerium, praseodymium, or terbium in the precursor rinse or seal baths from which some resultant

corrosion inhibition will be exhibited is probably in the range of 1×10^{-3} to 1×10^{-4} moles/liter of cerium, praseodymium, or terbium. We used cerium concentrations of approximately 1×10^{-1} mole/liter of cerium with excellent results.

5 3) Valence Stabilizer Concentrations

The concentration of the valence stabilizer can be any concentration up to the maximum solubility of the specific valence stabilizer source used. Any concentration exceeding this solubility will result in undissolved solid material that will not be available for stabilizing the desired tetravalent cerium, praseodymium, or terbium ions. If the valence stabilizer is also used to color the coating (i.e., an anodized aluminum), high concentrations will result in darker shades. The concentration of valence stabilizer source should be restricted to its maximum solubility in water at or near ambient temperature (25°C). Higher temperatures may allow more valence stabilizer to be added to the rinse or seal solutions, but this would result in precipitation if the solutions were allowed to cool. Table 5 shows the aqueous solubility of some of the more desirable sources for wide band inorganic valence stabilizers, and Table 6 shows the aqueous solubility of some sources of narrow band inorganic valence stabilizers.

Table 5
Solubilities of Wide Band Inorganic Valence Stabilizer Precursors
Under Ambient Conditions
[Maximum Allowable Concentrations in Solution]
(At or near 25°C and at or near pH 7)

Wide Band Inorganic Valence Stabilizer	Example Precursors	Solubility in Water (mole/L)
Molybdates	Molybdenum trioxide	7.4×10^{-3}
	Molybdic acid	7.4×10^{-3}
	Ammonium molybdate	5×10^0
	Lithium molybdate	1×10^1
	Sodium molybdate	2.15×10^2
	Potassium molybdate	7.75×10^2
	Rubidium molybdate	6.4×10^0
	Cesium molybdate	4.8×10^0
	Magnesium molybdate	7.4×10^{-1}
Tungstates	Tungstic acid	8.0×10^{-1}
	Ammonium tungstate	1×10^2
	Lithium tungstate	5.8×10^1
	Sodium tungstate	2.49×10^2

	Potassium tungstate Rubidium tungstate Cesium tungstate Magnesium tungstate hydrate	1.42×10^2 5×10^1 5×10^0 7.2×10^{-1}
Vanadates	Vanadium pentoxide Ammonium vanadate Lithium vanadate Sodium vanadate Potassium vanadate Rubidium vanadate Cesium vanadate Magnesium vanadate Calcium vanadate	4.4×10^{-2} 4.4×10^{-2} 1×10^0 1.7×10^0 1×10^0 5×10^{-1} 5×10^{-1} 1×10^0 5×10^{-1}
Niobates	Ammonium niobate Lithium niobate Sodium niobate Potassium niobate Magnesium hexaniobate Calcium hexaniobate	1×10^{-1} 1×10^{-1} 5.9×10^{-2} 5×10^{-2} 8.8×10^{-2} 4.7×10^{-2}
Tantalates	Ammonium tantalate Lithium tantalate Sodium tantalate Potassium tantalate	1×10^{-2} 1×10^{-2} 5.5×10^{-3} 5×10^{-3}
Tellurates	Telluric acid Ammonium tellurate Lithium tellurate Sodium tellurate Potassium tellurate Rubidium tellurate Cesium tellurate	5×10^{-1} 5×10^{-1} 1×10^0 2.8×10^{-2} 1×10^{-2} 1×10^{-2} 1×10^{-2}
Periodates	Periodic acid Ammonium periodate Lithium periodate Sodium periodate Potassium periodate Rubidium periodate Cesium periodate Magnesium periodate	4.96×10^1 1.3×10^{-1} 5×10^1 6.7×10^{-1} 2.9×10^{-2} 2.4×10^{-2} 6.6×10^{-2} 5×10^0
Antimonates	Ammonium antimonate Lithium antimonate Sodium antimonate Potassium antimonate Rubidium antimonate Cesium antimonate	1×10^0 1×10^0 1.2×10^{-3} 1.04×10^{-1} 1×10^{-1} 5×10^{-2}

Stannates	Ammonium stannate	5×10^0
	Lithium stannate	5×10^0
	Sodium stannate	2.3×10^0
	Potassium stannate	3.7×10^0
	Rubidium stannate	5×10^0
	Cesium stannate	1×10^0
Iodates	Iodic acid	1.76×10^1
	Iodine pentoxide	5.6×10^0
	Ammonium iodate	1.1×10^{-1}
	Lithium iodate	4.4×10^0
	Sodium iodate	4.5×10^{-1}
	Potassium iodate	2.2×10^{-1}
	Rubidium iodate	8.1×10^{-2}
	Cesium iodate	8.4×10^{-2}
	Magnesium iodate	2.29×10^{-1}
Phosphates	Phosphoric acid	5.6×10^1
	Ammonium phosphate	1.3×10^0
	Lithium phosphate	3.4×10^{-3}
	Sodium phosphate	2.6×10^{-1}
	Potassium phosphate	4.2×10^0
	Pyrophosphoric acid	4.0×10^1
	Sodium pyrophosphate	1.2×10^{-1}
Bromates	Ammonium bromate	1×10^1
	Lithium bromate	4.85×10^0
	Sodium bromate	1.82×10^0
	Potassium bromate	8.0×10^{-1}
	Rubidium bromate	1.4×10^{-1}
	Cesium bromate	1.4×10^{-1}
	Magnesium bromate	1.0×10^0
	Calcium bromate	1×10^0
	Strontium bromate	9.1×10^{-1}
	Zinc bromate	1×10^0
	Ferric bromate	$\sim 1 \times 10^0$
Nitrates	Nitric acid	75 wt. %
	Ammonium nitrate	2.5×10^1
	Lithium nitrate	1.3×10^1
	Sodium nitrate	1.1×10^1
	Potassium nitrate	7.4×10^0
	Rubidium nitrate	3.0×10^0
	Cesium nitrate	2.1×10^0
	Magnesium nitrate	4.9×10^0
	Calcium nitrate	2.1×10^1
	Strontium nitrate	3.4×10^0
	Zinc nitrate	6.2×10^0
	Barium nitrate	3.3×10^{-1}

	Aluminum nitrate	1.7×10^0
	Ferric nitrate	5.7×10^0
	Tetramethylammonium nitrate	$\sim 1 \times 10^1$
	Tetraethylammonium nitrate	$\sim 5 \times 10^0$
	Tetrapropylammonium nitrate	$\sim 1 \times 10^0$
	Tetrabutylammonium nitrate	$\sim 5 \times 10^{-1}$
Sulfates	Sulfuric acid	75 wt. %
	Ammonium sulfate	6.1×10^0
	Lithium sulfate	2.7×10^0
	Sodium sulfate	2.2×10^0
	Potassium sulfate	1.0×10^0
	Rubidium sulfate	1.7×10^0
	Cesium sulfate	5.0×10^0
	Magnesium sulfate	3.0×10^0
	Zinc sulfate	3.4×10^0
	Aluminum sulfate	3.0×10^0
	Ferric sulfate	7.9×10^0
Carbonates	Ammonium carbonate	8.8×10^0
	Ammonium bicarbonate	1.5×10^0
	Lithium carbonate	2.1×10^{-1}
	Lithium bicarbonate	8.1×10^{-1}
	Sodium carbonate	7.5×10^{-1}
	Sodium bicarbonate	8.2×10^{-1}
	Potassium carbonate	8.1×10^0
	Potassium bicarbonate	3.9×10^0
	Rubidium carbonate	1.95×10^1
	Rubidium bicarbonate	3.7×10^0
	Cesium carbonate	8.0×10^0
	Cesium bicarbonate	1.08×10^1

Table 6
Solubilities of Narrow Band Inorganic Valence Stabilizer Precursors
Under Ambient Conditions
[Maximum Allowable Concentrations in Solution]
(At or near 25°C and at or near pH 7)

5

Narrow Band Inorganic Valence Stabilizer	Example Precursors	Solubility in Water (mole/L)
Germanates	Germanium dioxide hydrate	4.3×10^{-2}
	Ammonium germanate	1×10^0
	Lithium germanate	6.3×10^{-2}
	Sodium germanate	1.55×10^0
	Potassium germanate	1×10^0
	Rubidium germanate	5×10^{-1}
	Cesium germanate	5×10^{-1}
Titanates	Titanium hydroxide	1.36×10^{-4}
Zirconates	Zirconium hydroxide	1.26×10^{-3}
Selenates	Selenic acid	60 wt. %
	Ammonium selenate	6.0×10^0
	Sodium selenate	1.2×10^0
	Potassium selenate	5.0×10^0
Bismuthates	Bismuth nitrate	2.7×10^{-2}
	Bismuthyl perchlorate	1×10^{-1}
Arsenates	Arsenic pentoxide	6.5×10^0
	Ammonium arsenate	2.1×10^0
	Sodium arsenate	9.2×10^{-1}
	Potassium arsenate	7.4×10^{-1}
Silicates	Sodium silicate	1×10^0
	Potassium silicate	1×10^0
Borates	Boric acid	1.1×10^0
	Ammonium borate	2.8×10^{-1}
	Lithium borate	5.2×10^{-1}
	Sodium borate	3.9×10^0
	Potassium borate	8.7×10^0
Aluminates	Sodium aluminate	1×10^0
	Potassium aluminate	1×10^0

The maximum concentration of organic valence stabilizers is also dependent upon precursor solubility. Because of the very large number of potential organic valence stabilizers, precursor solubilities are not shown.

The minimum concentration of valence stabilizer is dependent upon the specific Ce^{+4} -, Pr^{+4} -, or Tb^{+4} -valence stabilizer complex being formed within the rinsed or sealed coating. The number of complexing octahedra or icosahedra around the central Ce^{+4} ion varies from species to

species (e.g., molybdates vs. tungstates). Varying the concentration of the complexing agent while keeping the Ce^{+4} concentration constant resulted in clear differences in corrosion protection. The degree of corrosion protection was found to fall off dramatically below a valence stabilizer-to-cerium or valence stabilizer-to-praseodymium ratio of about 0.01.

- 5 Therefore, the minimum valence stabilizer-to-cerium, valence stabilizer-to-praseodymium, or valence stabilizer-to-terbium ratio is about 0.010, with ratios higher than 0.015 being typical.

4) Oxidizer Concentrations

The concentration of the oxidizer source can range up to the maximum solubility of the specific oxidizer source used. Any concentration exceeding this solubility will result in undissolved solid material that will not be available to raise the redox potential of the rinse or seal solution. The maximum concentration of oxidizer source should be restricted to its maximum solubility in water at or near ambient temperature (25°C). As discussed above, more oxidizer can be added to the solutions if the temperature is increased from ambient. Higher temperatures may lead to higher allowable concentrations of oxidizer precursors, but cooling of these solutions will result in reagent precipitation. Table 7 shows the solubilities in water of some of the more desirable oxidizer sources.

Table 7
Solubilities of Some Oxidizer Sources under Ambient Conditions
[Maximum Concentration of Oxidizer in Solution]
(At or near 25°C and at or near pH 7)

Oxidizer Source	Example Precursor	Solubility in Water (mole/L)
Peroxides and superoxides	Hydrogen peroxide	60 wt. %
	Lithium peroxide	1×10^0
	Sodium peroxide	1×10^0
	Potassium superoxide	1×10^0
Persulfates	Ammonium persulfate	2.6×10^0
	Lithium persulfate	3×10^0
	Sodium persulfate	3.1×10^0
	Potassium persulfate	2.0×10^{-1}
	Magnesium persulfate	1×10^{-1}
	Calcium persulfate	1×10^{-1}
	Strontium persulfate	5×10^0
	Barium persulfate	1.3×10^0
Perborates	Ammonium perborate	1.8×10^{-1}

	Lithium perborate	1×10^{-1}
	Sodium perborate	1.7×10^{-1}
	Potassium perborate	1.1×10^{-1}
Peroxybenzoates	Monoperoxyphthalic acid	1×10^1
	Magnesium monoperoxyphthalate	1×10^1
	Chloroperoxybenzoic acid	1×10^1
Chlorites	Lithium chlorite	5×10^0
	Sodium chlorite	4.3×10^0
	Calcium chlorite	1×10^0
	Strontium chlorite	5×10^{-1}
	Barium chlorite	1×10^{-1}
Bromates	Ammonium bromate	1×10^1
	Lithium bromate	4.85×10^0
	Sodium bromate	1.82×10^0
	Potassium bromate	8.0×10^{-1}
	Rubidium bromate	1.4×10^{-1}
	Cesium bromate	1.4×10^{-1}
	Magnesium bromate	1.1×10^0
	Calcium bromate	$1.2 \sim 1 \times 10^0$
	Strontium bromate	9.1×10^{-1}
	Zinc bromate	1×10^0
	Ferric bromate	1×10^0
Hypochlorites	Lithium hypochlorite	1×10^1
	Sodium hypochlorite	1×10^1
	Magnesium hypochlorite	1×10^1
	Calcium hypochlorite	1×10^1
	Strontium hypochlorite	5×10^0
	Barium hypochlorite	5×10^0
Periodates	Periodic acid	4.96×10^1
	Ammonium periodate	1.3×10^{-1}
	Lithium periodate	1×10^0
	Sodium periodate	6.7×10^{-1}
	Potassium periodate	2.9×10^{-2}
	Rubidium periodate	2.4×10^{-2}
	Cesium periodate	6.6×10^{-2}
	Magnesium periodate	1×10^{-2}

Chlorates	Lithium chlorate	5.5×10^1
	Sodium chlorate	7.5×10^0
	Potassium chlorate	5.8×10^{-1}
	Rubidium chlorate	3.0×10^{-1}
	Cesium chlorate	2.9×10^{-1}
	Magnesium chlorate	4.3×10^0
	Calcium chlorate	7.4×10^0
	Strontium chlorate	6.9×10^0
	Zinc chlorate	8.6×10^0
	Barium chlorate	8.5×10^{-1}
Perchlorates	Perchloric acid	75 wt. %
	Ammonium perchlorate	1.1×10^0
	Lithium perchlorate	5.6×10^0
	Sodium perchlorate	1.2×10^1
	Potassium perchlorate	3.6×10^{-1}
	Rubidium perchlorate	2.2×10^{-1}
	Cesium perchlorate	8.6×10^{-2}
	Magnesium perchlorate	4.4×10^0
	Calcium perchlorate	7.9×10^0
	Strontium perchlorate	1.3×10^1
	Zinc perchlorate	1×10^0
	Barium perchlorate	5.1×10^0
	Aluminum perchlorate	1×10^0
	Ferric perchlorate	1×10^0
	Me_4N^+ perchlorate	1×10^0
	Et_4N^+ perchlorate	5×10^{-1}
	Pr_4N^+ perchlorate	1×10^{-1}
Nitrates	Nitric acid	75 wt. %
	Ammonium nitrate	2.5×10^1
	Lithium nitrate	1.35×10^1
	Sodium nitrate	1.15×10^1
	Potassium nitrate	7.4×10^0
	Rubidium nitrate	3.0×10^0
	Cesium nitrate	2.1×10^0
	Magnesium nitrate	4.9×10^0
	Calcium nitrate	2.15×10^1
	Strontium nitrate	3.4×10^0
	Zinc nitrate	6.2×10^0
	Barium nitrate	3.3×10^{-1}
	Aluminum nitrate	1.75×10^0
	Ferric nitrate	5.7×10^0
	Me_4N^+ nitrate	1×10^1
	Et_4N^+ nitrate	5×10^0
	Pr_4N^+ nitrate	1×10^0
	Bu_4N^+ nitrate	5×10^{-1}
Nitrites	Lithium nitrite	2.8×10^1

	Sodium nitrite	1.35×10^1
	Potassium nitrite	3.5×10^1
	Magnesium nitrite	1×10^0
	Calcium nitrite	3.9×10^0
	Strontium nitrite	3.8×10^0
	Zinc nitrite	1×10^0
	Barium nitrite	2.9×10^0
Vanadates	Vanadium pentoxide	4.4×10^{-2}
	Ammonium vanadate	4.4×10^{-2}
	Lithium vanadate	1×10^0
	Sodium vanadate	1.7×10^0
	Potassium vanadate	1×10^0
	Rubidium vanadate	5×10^{-1}
	Cesium vanadate	5×10^{-1}
	Magnesium vanadate	1×10^0
	Calcium vanadate	5×10^{-1}
Iodates	Iodic acid	1.76×10^1
	Iodine pentoxide	5.6×10^0
	Ammonium iodate	2.6×10^{-1}
	Lithium iodate	4.4×10^0
	Sodium iodate	4.5×10^{-1}
	Potassium iodate	2.2×10^{-1}
	Rubidium iodate	8.1×10^{-2}
	Cesium iodate	8.4×10^{-2}
	Magnesium iodate	2.29×10^{-1}
Permanganates	Ammonium permanganate	5.77×10^{-1}
	Lithium permanganate	3.97×10^0
	Sodium permanganate	1×10^0
	Potassium permanganate	4.04×10^{-1}
	Magnesium permanganate	1×10^1
	Calcium permanganate	9.18×10^0
	Strontium permanganate	7.67×10^0
	Barium permanganate	2.01×10^0
	Zinc permanganate	8.10×10^{-1}
	Ferric permanganate	1×10^0

Low oxidizer concentrations may not oxidize a sufficient quantity of cerium, praseodymium, or terbium from the trivalent state to the tetravalent state. This would result in reduced corrosion-inhibiting performance. The redox potential of the coating solutions tends to decrease slowly with time (e.g., several days), so these solutions typically need additions of oxidizer to maintain the redox potential. The net redox potential of the coating solution is also a function of the surface area of the metal that has been coated.

5) Preparative Agent Concentrations

The concentration of the optional preparative agent is also important for the rinse and sealing solutions. If used, the concentration of the fluoride generally should not exceed 0.5 M (up to 5.0 M F⁻ can be used for some specialized applications, such as on anodized titanium or magnesium). Careful control of the available F⁻ should be exercised so that excessive back-etching of the existing barrier layer (e.g., phosphate or hydroxide/oxide) does not occur. In some applications (i.e., anodized aluminum that is to be color dyed) it may be desirable to have no preparative agent at all. Solubility values for many fluorides (the typical preparative agent) are given in Table 8. Of course, variations in the solution temperature and pH will change the solubilities of each of these preparative agents, but the values given below can be used as general approximations.

Table 8
Solubilities of Fluoride Preparative Agents under Ambient Conditions
[Maximum Allowable Concentrations in Solution]
(At or near 25°C and at or near pH 7)

Fluoride Source	Example Precursor	Solubility in Water (mole/L)
Simple Fluorides	Hydrofluoric acid	75 wt. %
	Ammonium fluoride	2.7×10^1
	Lithium fluoride	1.04×10^{-1}
	Sodium fluoride	1.01×10^0
	Potassium fluoride	1.59×10^1
	Potassium bifluoride	5.25×10^0
	Rubidium fluoride	1.25×10^1
	Cesium fluoride	2.42×10^1
	Copper (II) fluoride	4.62×10^{-1}
	Silver (I) fluoride	1.43×10^1
	Zinc fluoride	1.57×10^{-1}
	Aluminum fluoride	6.6×10^{-2}
	Titanium fluoride	1×10^0
	Zirconium fluoride	8.3×10^{-2}
	Germanium fluoride hydrate	1×10^{-1}
	Tin (II) fluoride	1×10^{-1}
	Tin (IV) fluoride	1×10^0
	Vanadium fluoride	1×10^{-1}
	Niobium fluoride	1×10^0
	Tantalum fluoride	1×10^{-1}
	Antimony (III) fluoride	3.15×10^{-1}
	Antimony (V) fluoride	1×10^0

	Manganese (II) fluoride	7.1×10^{-2}
	Cobalt (II) fluoride	1.55×10^{-1}
Hexafluorozirconates	Ammonium fluorozirconate	1×10^{-1}
	Lithium hexafluorozirconate	8×10^{-2}
	Sodium hexafluorozirconate	6×10^{-2}
	Potassium hexafluorozirconate	8.12×10^{-2}
	Rubidium hexafluorozirconate	8.48×10^{-2}
	Cesium hexafluorozirconate	1.12×10^{-1}
Hexafluorotitanates	Ammonium hexafluorotitanate	1×10^{-1}
	Lithium hexafluorotitanate	5×10^{-2}
	Sodium hexafluorotitanate	1×10^{-2}
	Potassium hexafluorotitanate	6.0×10^{-2}
	Rubidium hexafluorotitanate	2.5×10^{-2}
	Cesium hexafluorotitanate	5.5×10^{-2}
Hexafluorosilicates	Ammonium hexafluorosilicate	1.04×10^0
	Lithium hexafluorosilicate	3.8×10^0
	Sodium hexafluorosilicate	3.5×10^{-2}
	Potassium hexafluorosilicate	5.5×10^{-3}
	Rubidium hexafluorosilicate	6.9×10^{-3}
	Cesium hexafluorosilicate	2.3×10^{-2}
	Silver (I) hexafluorosilicate	1×10^0
	Magnesium hexafluorosilicate	3.9×10^0
	Calcium hexafluorosilicate	5×10^{-1}
	Strontium hexafluorosilicate	1.1×10^{-1}
	Zinc hexafluorosilicate	1.11×10^0
	Copper (II) hexafluorosilicate	7.4×10^0
	Cobalt (II) hexafluorosilicate	3.82×10^0
	Manganese (II) Fluorosilicate	4.59×10^0
	Iron (II) hexafluorosilicate	4.19×10^0
	Iron (III) hexafluorosilicate	"soluble"
Hexafluoroaluminates	Ammonium fluoroaluminate	5.3×10^{-2}
	Lithium hexafluoroaluminate	6.6×10^{-3}
	Sodium hexafluoroaluminate	2.9×10^{-3}
	Potassium fluoroaluminate	6.1×10^{-3}
Tetrafluoroborates	Ammonium tetrafluoroborate	2.4×10^0
	Lithium tetrafluoroborate	5×10^0
	Sodium tetrafluoroborate	9.8×10^0
	Potassium tetrafluoroborate	3.5×10^{-2}
	Rubidium tetrafluoroborate	1×10^{-1}
	Cesium tetrafluoroborate	5×10^{-1}
Hexafluorogermanates	Ammonium fluorogermanate	1×10^0
	Lithium hexafluorogermanate	1×10^0
	Sodium hexafluorogermanate	1×10^{-2}
	Potassium fluorogermanate	2.2×10^{-2}
	Rubidium fluorogermanate	1.7×10^{-2}
	Cesium hexafluorogermanate	

		4.7×10^{-2}
Hexafluorostannates	Ammonium fluorostannate Lithium hexafluorostannate Sodium hexafluorostannate Potassium hexafluorostannate Rubidium hexafluorostannate Cesium hexafluorostannate	1×10^{-1} 1×10^{-2} 1×10^{-2} 1.28×10^{-1} 6.2×10^{-2} 7.9×10^{-2}
Hexafluorohafnates	Ammonium hexafluorohafnate Lithium hexafluorohafnate Sodium hexafluorohafnate Potassium hexafluorohafnate Rubidium hexafluorohafnate Cesium hexafluorohafnate	1×10^0 1×10^{-1} 7×10^{-2} 1.3×10^{-1} 1.9×10^{-1} 1.7×10^{-1}
Fluorogallates	Ammonium fluorogallate Alkali/Alkaline fluorogallates Silver (I) fluorogallate Copper (II) fluorogallate Zinc fluorogallate Manganese (II), iron (II), and cobalt (II) fluorogallates	1×10^{-2} 1×10^{-2} 1×10^0 1×10^{-2} 1×10^{-1} 1×10^{-2}
Hexafluorophosphates	Ammonium fluorophosphate Lithium hexafluorophosphate Sodium hexafluorophosphate Potassium fluorophosphate Rubidium fluorophosphate Cesium hexafluorophosphate	1×10^0 2×10^0 5.6×10^0 5.1×10^{-1} 1×10^{-1} 1×10^{-1}
Hexafluoroantimonates	Ammonium fluoroantimonate Lithium hexafluoroantimonate Sodium hexafluoroantimonate Potassium fluoroantimonate Rubidium fluoroantimonate Cesium hexafluoroantimonate	4.7×10^0 1×10^0 4.97×10^0 3.7×10^0 1.6×10^0 5×10^0
Heptafluoroniobates	Lithium heptafluoroniobate Sodium heptafluoroniobate Potassium heptafluoroniobate Rubidium heptafluoroniobate Cesium heptafluoroniobate	5×10^{-1} 5×10^{-2} 2.6×10^{-1} 1×10^{-1} 3×10^{-1}
Heptafluorotantalates	Lithium heptafluorotantalate Sodium heptafluorotantalate Potassium heptafluorotantalate Rubidium heptafluorotantalate Cesium heptafluorotantalate	5×10^{-1} 5×10^{-2} 3×10^{-1} 1×10^{-1} 3×10^{-1}

6) Solubility Control Agent Concentrations

The concentration of the optional solubility control agent can be any concentration up to its maximum solubility under ambient conditions. Exceeding the solubility will result in undissolved solid material that will not be available for adjusting the solubility of the cerium-,
5 praseodymium-, or terbium-stabilizer complex. The solubilities of potential solubility control agents are not shown because of the large number of cationic or anionic species which can be used. Standard values for the solubilities of these materials in water can be used as the maximum allowable concentrations in the prepared solutions.

10 7) Rinse/Seal Solution pH

The rinse or seal solutions should have a slightly acidic or neutral pH so that a rise in pH caused by 1) interaction with the already-formed, hydrated barrier film (no preparative agent) or 2) barrier layer dissolution (with preparative agent) will result in a rise in local pore pH and the precipitation of the desired inhibitor species. Solution pH must not be so low that the pH rise
15 during the rinsing or sealing process is insufficient to result in inhibitor precipitation. Very low pH values will result in excessive dissolution of the existing barrier film.

The maximum practical pH of the rinse or sealing solution is about 9, and the lowest practical pH is -1.5. Optimally, however, the pH of the rinse or sealing solutions should not be higher than about 8 or lower than about 1 or 2. For anodized aluminum that is to be colored, the
20 pH range can be from about 4.5 to about 6.5. The pH of the tetravalent cerium, praseodymium, or terbium sealing or rinsing solutions should be checked periodically to confirm that it falls within operational parameters. Separate solutions that contain either valence stabilizers or optional solubility control agents generally do not require careful pH control.

25 8) Redox Potential of the Coating Solution

The necessary oxidation-reduction (redox) potential of the rinse or sealing solution is a function of both the solution pH and the cerium, praseodymium, or terbium concentration. Approximate values for the necessary redox potential of the cerium solution can be derived from the Pourbaix diagram for cerium and are shown in Table 9. Tetravalent cerium may be produced
30 in solution at slightly lower redox values than those in Table 9 if the cerium is already complexed with suitable valence stabilizers. Tetravalent praseodymium or terbium may also be

formed in a coating, provided that the redox potential is sufficiently high, and that the optimum valence stabilizer for Pr^{+4} and/or Tb^{+4} is used. An approximate value of the necessary redox potential for Pr^{+4} and Tb^{+4} can be derived by adding 0.3 to 0.4 V to those shown in Table 9.

5

Table 9
Approximate Potential as a Function of Rinse or Sealing Solution pH

pH	Minimum Redox Potential (V)
0	1.7
1	1.6
2	1.5
3	1.3
4	1.1
5	1.0
6	0.8
7	0.7

These redox potentials can be achieved through chemical (or electrochemical) means.

- 10 We have observed that the redox potential of these solutions will slowly drop over a period of several days. The redox potential of the rinse or sealing solution should be brought back up to those values shown in Table 9 if this occurs. Periodic evaluation of the redox potential of these solutions can be achieved using ASTM D 1498 (Oxidation-Reduction Potential of Water) or comparable test procedures. The redox potential of any post-treatment solution that contains
- 15 valence stabilizer or optional additional solubility control agent does not require control.

9) Application Temperature

- The application temperature can be any temperature between the freezing and boiling points of the rinse or sealing solution, although temperatures at or near ambient (20-25°C) are
- 20 desirable in view of process economics. A typical temperature range is therefore between about 20 and about 50°C. Application temperatures that are cooler than the typical range will result in a much slower coating deposition rate and may result in incomplete film formation.
- Temperatures higher than the typical range (e.g., about 50 to about 100°C) can be used, especially to increase the hydration of the existing barrier layer. This will lead to a much more
- 25 rapid pH rise in the pores to be treated, thereby further enhancing inhibitor formation and

precipitation. If coloring is desired (i.e., on anodized aluminum), higher sealing temperatures will result in darker shades. However, the economics associated with a substantial temperature increase over ambient is balanced against the benefits derived from this additional energy expenditure, especially if less costly methods to reach the same performance (e.g., use of a preparative agent) are available.

10) Contact Time

The contact time for the solutions should be sufficient to allow the formation of a tetravalent cerium, praseodymium, or terbium inhibitor species within the pores of the treated coating. A minimum contact time of about 1 minute under ambient conditions to an average time of about 5 minutes should be appropriate. A maximum contact time of 30 minutes may be acceptable under some circumstances (i.e., for anodized aluminum). Longer immersion times will result in darker shades on colored coatings. Rinse or sealing solutions kept in contact with the work piece for longer times did not appear to produce adverse effects on the test specimens.

A) GENERAL APPLICATION PROCESS

The general process flow diagram for the application of the optimized tetravalent cerium, praseodymium, or terbium rinse or seal solutions is as follows for a typical work piece:

- a) Precleaning (if required)
- b) Masking (if required)
- c) Alkaline cleaning/rinsing; or other cleaning process
- d) Deoxidizing/pickling/rinsing (if required)
- e) Formation of barrier film (e.g., those listed in Table 1)
- f) Rinsing (if required)
- g) Application of tetravalent cerium, praseodymium, and/or terbium rinsing or sealing solution
- h) Rinsing (optional)
- i) Post-coating treatment (if stabilizer or cerium, praseodymium, or terbium not included in original solution)
- j) Rinsing
- k) Hot water seal (optional)

- l) Drying (if required)
- m) Application of other coatings

Each of these processing steps are discussed briefly as follows:

5

- a) Precleaning (if required)

Heavy oils or greases on the part to be coated are removed using an appropriate technique, such as vapor degreasing.

- 10 b) Masking (if required)

Any areas that are not to be coated with the barrier film are masked off using appropriate maskants. Any system component that may be adversely affected by the barrier film coating process should also be masked off.

- 15 c) Alkaline Cleaning/Rinsing

Alkaline cleaning is performed using appropriate alkaline cleaning solutions in accordance with manufacturers' specifications in order to remove small traces of oils or hydrocarbon contaminants on the metal surface. These alkaline cleaning solutions typically need elevated temperatures for application. Following alkaline cleaning, the metal piece should be
20 rinsed while reducing as much drag-out as possible from the alkaline cleaning bath.

- d) Deoxidizing/Pickling/Rinsing

Deoxidizing or pickling should be performed using appropriate deoxidizing solutions in accordance with performance specifications in order to remove the natural oxide film on the
25 surface of the metal piece. Following deoxidizing or pickling, the metal piece is thoroughly rinsed while reducing as much drag-out as possible from the deoxidizing bath.

- e) Formation of Barrier Coating

The barrier coating is formed either through immersion, spray application, fogging, or
30 manual application using methodologies that are described for each specific process. Table 1

describes some of the barrier film formation processes that can be treated using the embodiments contained herein.

f) Rinsing (if required)

5 Standard rinse procedures are used. Rinsing after the formation of the barrier film is almost always necessary. For phosphate barrier films, this is especially important. This rinse helps to avoid blistering of any subsequently applied paint from residual phosphating solution, as well as to prevent contamination of the rinsing or sealing solution if the work piece is to be dipped. A thorough deionized water rinse, especially around holes or slots, or in crevices of the
10 work piece, is frequently used. The temperature of these rinses is typically between about 20 and about 50°C, with exposure times of approximately 2 minutes. For some anodic coatings, agents such as bicarbonate, oxalic acid, or phthalic acid are sometimes added.

g) Application of Tetravalent Cerium, Praseodymium, and/or Terbium Rinsing or Sealing
15 Solution

The rinsing or sealing solution is applied through immersion, spray application, fogging, or manual application using embodiments discussed herein.

h) Rinsing (optional)

20 Rinsing is typical after application of the cerium, praseodymium, and/or terbium rinsing or sealing solution. In some instances (e.g., if a subsequent valence stabilizer or solubility control agent solution is to be applied), it may not be advisable to rinse.

i) Post-Coating Treatment

25 If the tetravalent cerium, praseodymium, and/or terbium stabilizer is not included in the original rinse or sealing bath, then a second solution application (either by immersion, spray application, fogging, or manual application) is necessary. This second solution application would contain the cerium, praseodymium, and/or terbium valence stabilizer. If the valence stabilizer is contained in the first treatment (see step g) above) without cerium, praseodymium, or
30 terbium then the cerium, praseodymium, or terbium would be included in this treatment.

Likewise, if additional solubility control is necessary, then this can be achieved through the application of a post-treatment solution.

j) Rinsing

5 Standard rinse procedures are used.

k) Hot water seal (optional)

If further sealing of the coating (especially for anodic coatings) is desired, a hot water (>50°C) seal using pure water can be applied. Bleaching of the coating to remove color can also
10 be performed at this point.

l) Drying (if required)

Standard drying method may be used.

15 m) Application of other coatings

Application of other coatings is performed at this time. For items that are to be used as wear materials (i.e., manganese, zinc phosphate, or black oxide coatings from step e), this frequently involves an oil dip. For anodized coatings, a post-treatment composed of silicates, polymers, or lacquers is frequently applied.

20

While the invention has been described by reference to certain embodiments, it should be understood that numerous changes could be made within the spirit and scope of the inventive concepts described. Accordingly, it is intended that the invention not be limited to the disclosed embodiments, but that it have the full scope permitted by the language of the following claims.

25 We claim: